HUC 10290102 - Lower Marais Des Cygnes
Water body ID: 1300
Pollutant(s): Low dissolved oxygen

Revised
Total Maximum Daily Load
for
Mound Branch
Bates County

Submitted: March 31, 2022
Updated: June 13, 2022
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Impairment: Dissolved Oxygen

Prepared by: Water Protection Program, Watershed Protection Section

WATER BODY SUMMARY
Total Maximum Daily Load for Mound Branch
Pollutants: Low dissolved oxygen

Name: Mound Branch

Location: Bates County near Butler

8-digit Hydrologic Unit Code (HUC):[1]
10290102 – Lower Marais Des Cygnes

12-digit HUC Subwatersheds:
102901020504 – Mound Branch

Water Body Identification Number (WBID) and Hydrologic Class:[2]
WBID 1300 – Class C

Designated Uses:[3]
Irrigation
Livestock and wildlife protection
Human health protection
Warm water habitat (aquatic life)
Whole body contact recreation category B
Secondary contact recreation

Impaired Use:
Warm water habitat (aquatic life)

Pollutants and Sources Identified on the 2008 303(d) List:
Low dissolved oxygen – Unknown source

Length and Location of Impaired Segment
8.9 miles (14.3 kilometers), from mouth to Section 13, Township 40N, Range 31W

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[1] Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 2,270 8-digit hydrologic units (USGS 2019). A hydrologic unit is a drainage area delineated to nest in a multilevel, hierarchical drainage system. A hydrologic unit code is the numerical identifier of a specific hydrologic unit consisting of a 2-digit sequence for each specific level within the delineation hierarchy (FGDC 2003).

[2] For hydrologic classes see 10 CSR 20-7.031(1)(F). Class C streams may cease flow in dry periods, but maintain permanent pools that support aquatic life.

[3] For designated uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H. Presumed uses are assigned per 10 CSR 20-7.031(2)(A) and (B) and are reflected in the Missouri Use Designation Dataset described at 10 CSR 20-7.031(2)(E).

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1. Introduction

The Missouri Department of Natural Resources in accordance with Section 303(d) of the federal Clean Water Act is establishing this total maximum daily load (TMDL) to address the low dissolved oxygen impairment in Mound Branch near Butler in Bates County. This Revised TMDL supersedes the TMDL approved by the U.S. Environmental Protection Agency (EPA) on May 26, 2010, that was established to meet the milestones of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. Mound Branch was first listed on the 1998 Missouri 303(d) List of impaired waters for biochemical oxygen demand and ammonia with the Butler Wastewater Treatment Facility identified as the primary source.[4] Mound Branch remained listed as impaired by biochemical oxygen demand and ammonia on the 2002 303(d) List. On the combined 2004/2006 303(d) List these pollutants were changed from biochemical oxygen demand to low dissolved oxygen and ammonia was delisted. Mound Branch remained listed as impaired by low dissolved oxygen on the 2008 303(d) List.

Section 303(d) of the federal Clean Water Act and Title 40 of the Code of Federal Regulations (CFR) Part 130 require states to develop TMDLs for waters not meeting applicable water quality standards. Missouri's Water Quality Standards at Title 10 of the Code of State Regulations (CSR) Division 20 Chapter 7.031 consist of three major components: designated uses, water quality criteria to protect those uses, and an antidegradation policy. The purpose of a TMDL is to determine the loading capacity of a specific pollutant that a water body can assimilate without exceeding the applicable Water Quality Standards for that water body. The TMDL process quantitatively assesses impairment factors so that water quality-based controls can be established to reduce pollutant loading and to restore and protect the quality of Missouri's water resources. Based on the relationship between pollutant sources and in-stream water quality conditions, a TMDL is the sum of a wasteload allocation and a load allocation (40 CFR 130.2) with a margin of safety (federal Clean Water Act section 303(d)(1)(C)). The wasteload allocation is the fraction of the loading capacity apportioned to existing or future point sources. The load allocation is the fraction of the loading capacity apportioned to existing or future nonpoint sources and natural background. The margin of safety is a portion of the TMDL that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality (40 CFR 130.7), any uncertainty associated with the model assumptions, and data inadequacies.

2. Rationale for Revision

Since the original listing of Mound Branch, the Butler Wastewater Treatment Facility, which discharges effluent to the impaired segment of Mound Branch, has engineered improvements in treatment plant operation. In addition, greater understanding of the characteristics of Mound Branch and the surrounding watershed warrant a reevaluation of the impairment and the conditions for which water quality standards can be attained. Advances in geographical information systems (GIS) and additional information sources that have become available in the decade since the development of the original TMDL provide an opportunity to make such a reevaluation. New water quality data were collected from Mound Branch in 2015 allowing revised modeling assumptions and data inputs that are more representative of current hydrology and water quality in Mound Branch.

[4] The Department maintains current and past 303(d) lists and corresponding assessment worksheets online at dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/impaired-waters.

The Butler Wastewater Treatment Facility has implemented biological nutrient removal improvements since the development of the 2010 TMDL. These improvements, completed in 2013, have resulted in decreased nitrogen and phosphorus load downstream of the outfall. They provide additional reason for re-evaluating the water quality targets for attainment of water quality standards in Mound Branch.

The 2010 Mound Branch TMDL established total nitrogen (TN) and total phosphorus (TP) wasteload and load allocations based on EPA Level III Ecoregion 40 criteria (USEPA 2000). However, the Ecoregion 40 nutrient criteria targets were developed based on streams in pristine or near-pristine environments, and may not be representative of more localized reference conditions. The targets are not tied to specific biological conditions or Missouri's minimum dissolved oxygen criterion. Additionally, these federally recommended nutrient criteria use a statistic-based distributional approach that has little or no linkage to biological "cause and effect" responses or ecologically significant thresholds, and merely represents an administrative water quality protection policy that guides EPA's clean water programs. For these reasons, these targets may not be appropriate metrics for use as wasteload allocations for point source discharge from wastewater treatment facilities. The Department has revised the Mound Branch TMDL based on critical low flow dissolved oxygen data and has established pollutant targets that are proportionate to the existing land uses and geomorphic characteristics of Mound Branch and its contributing watershed. The pollutant targets in the revised TMDL have been established such that the 5.0 milligrams per liter (mg/L) minimum criterion for dissolved oxygen will be achieved. Such targets will result in restoration of the protection of warm water habitat (aquatic life) designated use in Mound Branch and will be protective of downstream uses.

The targets and information provided in this revised TMDL replace those found in the 2010 TMDL. The ultimate endpoint for this revised TMDL is to meet Missouri Water Quality Standards through attainment of the minimum dissolved oxygen criterion for the protection of aquatic life in warm water habitats of 5.0 mg/L. Compliance with this criterion will be determined in accordance with Department assessment procedures for federal Clean Water Act sections 305(b) and 303(d) reporting. All pollutant reductions necessary to achieve the TMDL targets calculated in this revised TMDL shall be implemented until such a point that water quality standards are attained. If all point source and nonpoint source pollutant targets are achieved, but water quality standards are not attained, then additional monitoring will be scheduled and the TMDL may be further revised.

3. Water Body and Watershed Descriptions

Mound Branch is a 17.5-mile tributary of Miami Creek and is located in Bates County near the City of Butler. The headwaters of Mound Branch originate approximately 0.5 mi northwest of the intersection of county roads NE 8004 and NE 2503. Approximately 8.9 mi of Mound Branch, from the confluence of Miami Creek to the confluence with East Mound Branch, are identified in Missouri's Water Quality Standards as water body identification (WBID) 1300. The area draining to this water body is represented by the entire 12-digit hydrologic unit code (HUC) 102901020504 covering approximately 51.2 mi^2.

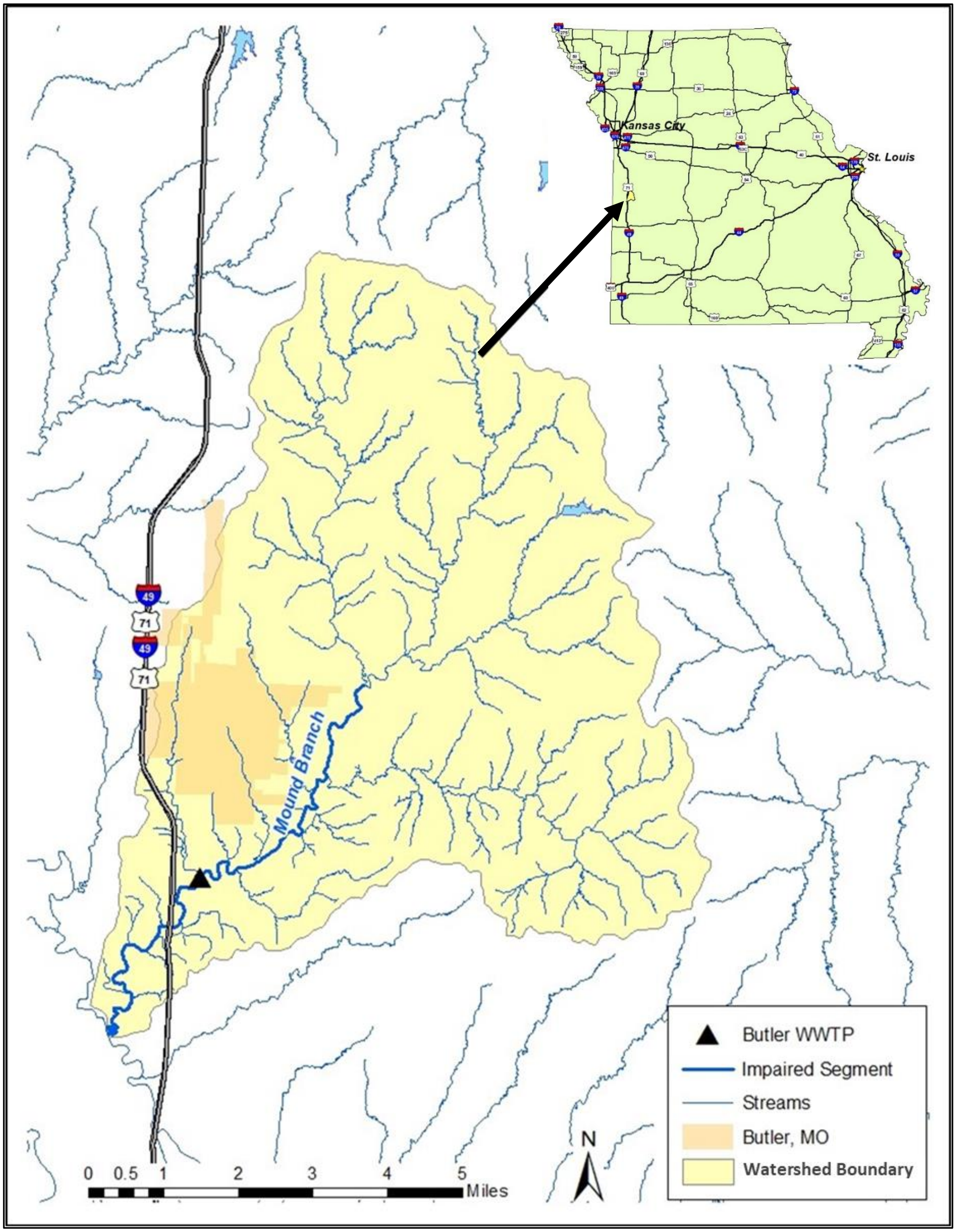

Figure 1. Mound Branch Watershed, 12-digit HUC 102901020504

3.1 Geology, Physiography and Soils

The Mound Branch watershed is located within the Osage/South Grand ecological drainage unit (EDU). Ecological drainage units are groups of watersheds that have similar biota, geography, and climate characteristics (USGS 2009). The Osage/South Grand EDU lies in eastern Kansas and west-central Missouri and includes Osage Plains in the western portion and Ozark Border in the eastern portion. The Mound Branch watershed is in the Osage Plains portion. The subsurface is composed of deep loess underlain by alternating beds of limestone, sandstone, shale, and coal. The sandstone and shale impede downward water movement so streams are primarily surface water dominated, and most small streams are ephemeral or intermittent. Even the largest streams have extremely low discharges during extended dry periods. Stream channels are highly meandering with extremely low gradients and high percentages of sand and silt in the substrate. Water is generally turbid with poor or absent riffles. Oxbow lakes, sloughs, and marshes were once common along the largest streams (MoRAP 2005).

The Mound Branch watershed is also located in the Wooded Osage Plains Level IV Ecoregion. The Wooded Osage Plains ecoregion is an undulating plain with smooth, low, limestone, escarpments, and small areas of exposed bedrock. Pennsylvanian limestone, sandstone, and shale strata with differential erosion has produced a rolling topography, and the potential natural vegetation is a mosaic of oak-hickory woodland and bluestem prairie (Chapman et al. 2002).

As presented in Table 1, the predominant soils in the contributing watershed consist of silt loam, clay loam, and silty clay loam. Although soils in the watershed are varied, they can be categorized based on similar runoff potentials into hydrologic soil groups. A hydrologic soil group indicates the rate at which water enters the soil profile under conditions of a bare, thoroughly wetted soil surface, which in turn may affect the potential amount of water entering the stream as runoff (NRCS 2009). Group A represents soils with the highest rate of infiltration and the lowest runoff potential. Group D soils have the lowest rate of infiltration and the highest potential for runoff. Group C soils have a low-moderate rate of infiltration and a moderate-high potential for runoff. Dual soil groups (e.g., B/D) account for the presence of a high water table by providing both the drained and undrained condition of the soil.[5] Table 2 provides a summary of the hydrologic soils groups in the Mound Branch watershed and Figure 2 shows their distribution. There are no Group A soils in the Mound Branch watershed.

[5] For the purpose of hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 24 inches (60 centimeters) below the surface in a soil where it would be higher in a natural state (NRCS 2009).

Table 1. Predominant Soils in the Mound Branch Watershed (NRCS 2017)

Soil Type and Description	Characteristics	Hydrologic Soil Group	Percentage of Watershed (%)
Kenoma silt loam, 1 to 3 percent slopes	Very deep, moderately well drained soils that formed in loess and/or old alluvial sediments; found on terraces and plains.	D	34.30%
Summit silty clay loam, 2 to 5 percent slopes	Very deep, moderately well drained and somewhat poorly drained soils that formed in clayey colluvium or residuum; found on interfluves, divides, and hillslopes.	D	8.60%
Hartwell silt loam, 0 to 1 percent slopes	Very deep, somewhat poorly drained soils formed in loess over old clayey alluvium and residuum; found on uplands.	C/D	7.90%
Deepwater silt loam, 2 to 5 percent slopes, eroded	Deep, moderately well drained, moderately permeable soils formed in a thin loess mantle and underlying residuum from shales.	C	7.30%
Coweta loam, 5 to 14 percent slopes	Shallow, well drained to somewhat excessively drained soils; found on uplands in the Cherokee Prairies.	D	7.20%
Bates loam, 1 to 3 percent slopes	Moderately deep, well drained soils found on interfluves and hillslopes.	C	6.00%
Verdigris silt loam, 0 to 3 percent slopes, occasionally or frequently flooded	Very deep, well drained soils that formed in silty alluvium on flood plains	C	5.60%
Eram silt loam, 2 to 5 percent slopes, eroded	Moderately deep, moderately well drained soils that formed from shale interbedded with thin layers of sandstone.	D	4.10%
Eram-Balltown complex, 5 to 20 percent slopes	Moderately deep, moderately well drained soils found on interfluves and ridges.	D	3.80%
Bucyrus silty clay loam, 1 to 3 percent slopes	Very deep, moderately well drained soils formed in a thin mantle of loess and the underlying residuum; found on nearly level to gently sloping summits, shoulders and side slopes on interfluves in the Cherokee Prairies.	C	3.30%
Other	All soil types that individually account for less than 2 percent of watershed area. Includes open water, gravel pits, and quarries.	--	12.10%

Table 2. Summary of Hydrologic Soil Groups in the Mound Branch Watershed (NRCS 2009)

Hydrologic Soil Group	Area (mi^2)	Area (%)
Not Rated (Open Water)	0.30	0.6%
B	1.79	3.5%
C	12.19	23.8%
C/D	4.04	7.9%
D	32.86	64.2%
Total	51.18	100.0%

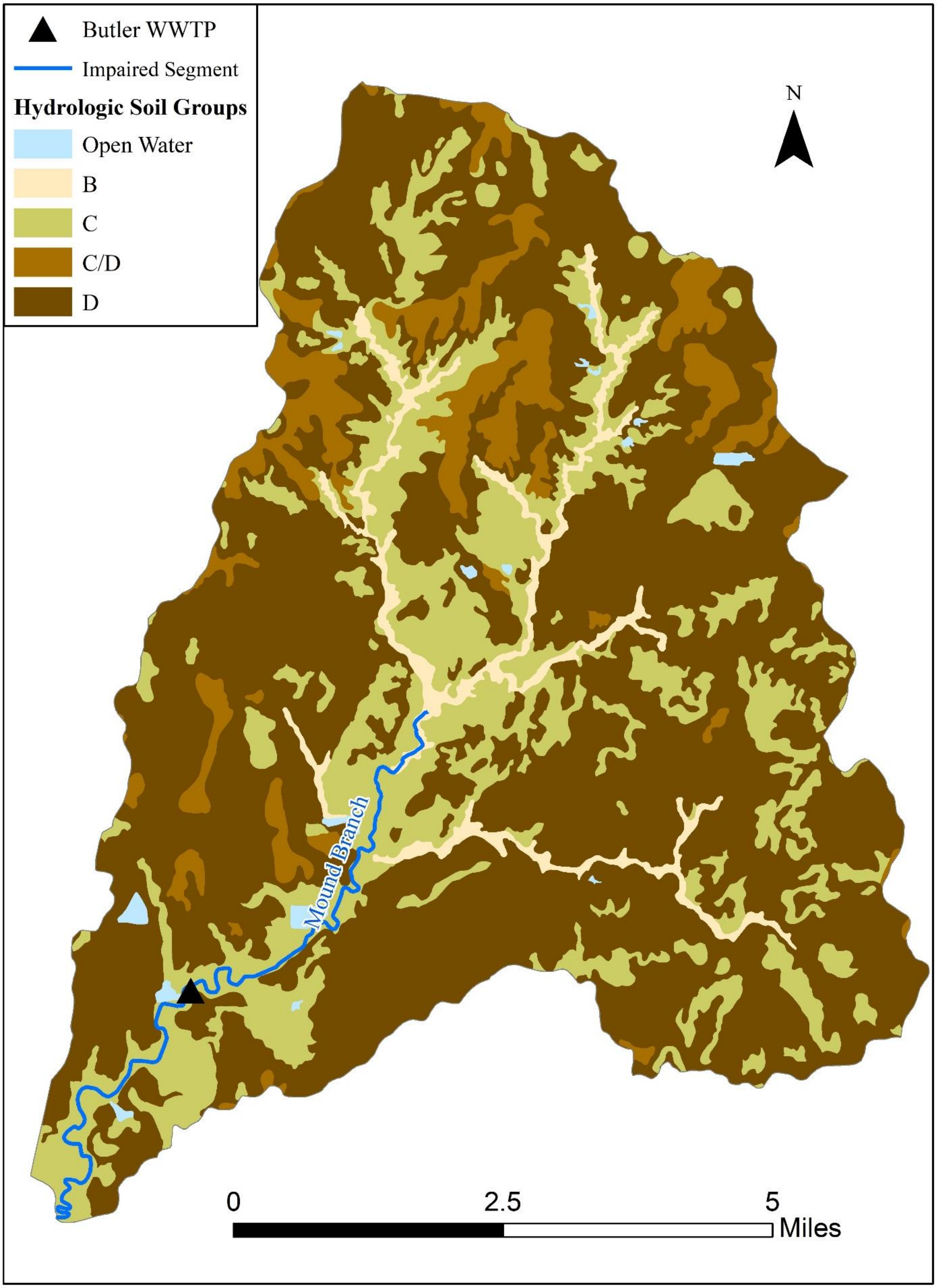

Figure 2. Hydrologic Soil Groups in the Mound Branch Watershed, 12-digit HUC 102901020504

3.2 Climate

Climate normals are 30-year averages of climatological variables, including temperature and precipitation, produced by the National Centers for Environmental Information every 10 years (NOAA 2010). The monthly precipitation and temperature normals are calculated using daily weather data from the Butler weather station (Station No. USC00231145) and are representative of the climatic conditions in the Mound Branch watershed. Of the various climatic factors, precipitation is especially important as it is related to stream flow and runoff events that can influence the transport of pollutants from nonpoint sources into streams. Water quality data recorded in August 2015, were used to model Mound Branch. Table 3 and Figures 3 and 4 compare 2015 temperature and precipitation data with the 30-year climate normal rainfall and temperature data observed at the Butler Weather Station. The U.S. Drought Monitor (University of Nebraska 2019) determined that the Lower Marais Des Cygnes HUC-8 was not in drought in 2015.

Table 3. Comparison of Climate Normals and 2015 Data at the Butler Weather Station No. USC00231145 (NOAA 2010)

	Precipitation (inches)		Mean Max. Temp. (ºF)		Mean Min. Temp. (ºF)	
Month	**Normal**	**2015**	**Normal**	**2015**	**Normal**	**2015**
January	1.52	0.36	39.9	42.6	19.4	18.4
February	1.93	1.15	46.1	37.8	23	16.4
March	2.84	0.9	56.8	57.2	32.8	31.6
April	4.28	4.09	66.2	69.2	43.1	45.6
May	5.91	9.21	75.5	74.7	54.6	54.3
June	6.31	7.03	83.8	84.8	64	67
July	4.15	5.63	89.1	87.4	68.9	69.3
August	3.68	3.42	88.7	85.4	66.4	64.1
September	4.40	5.6	80.4	82.7	56.9	61.3
October	3.77	1.71	69.6	71	45.1	48.5
November	3.04	7.46	55.9	59.8	33.6	36.7
December	2.16	5.41	42.9	51.8	23	30.6
	Total		**Average**		**Average**	
	43.99	51.97	66.24	67.03	44.23	45.32

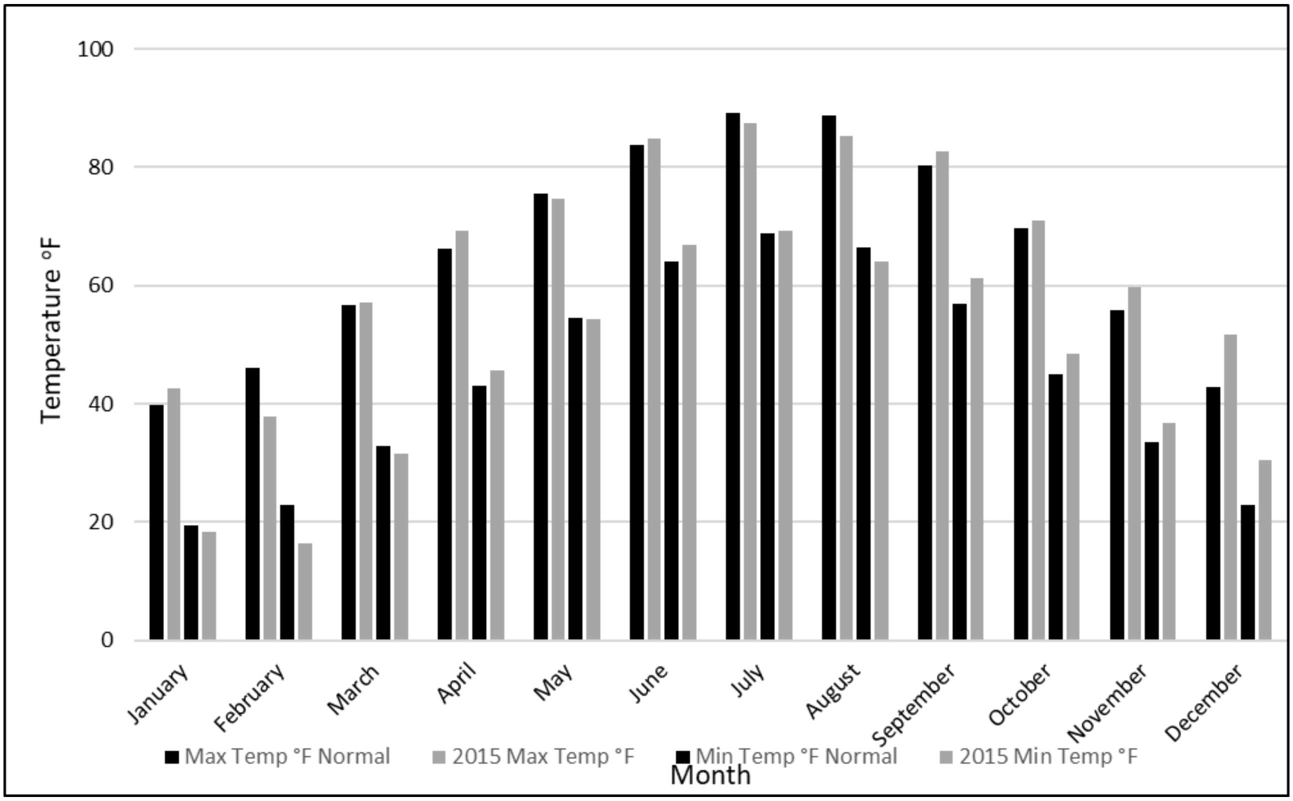

Figure 3. Comparison of Climate Normal and 2015 Average Monthly Minimum and Maximum Temperatures

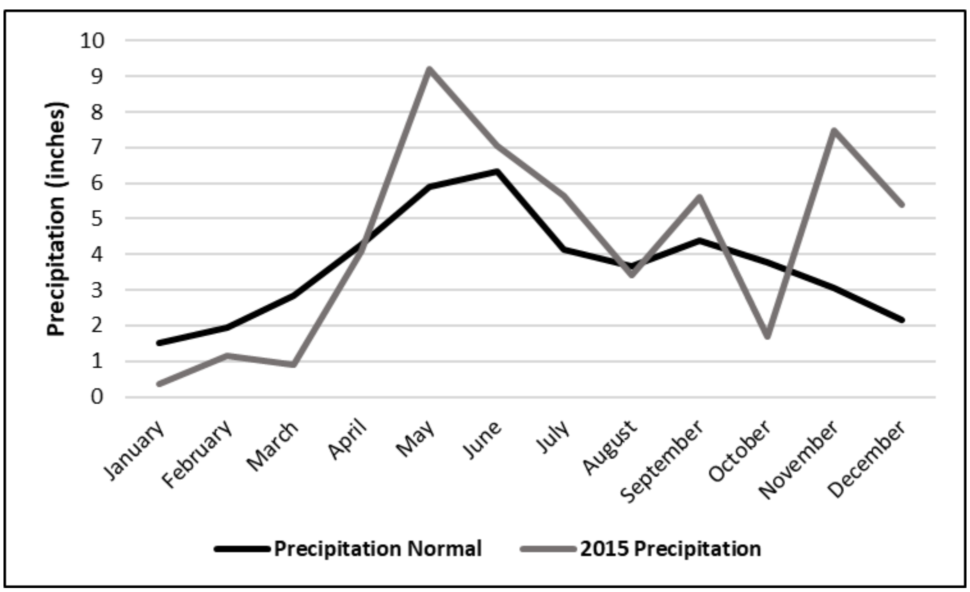

Figure 4. Comparison of Climate Normal and 2015 Average Monthly Precipitation

3.3 Population

The population estimates presented in Table 4 were derived using GIS software and superimposing the watershed boundary over a map of census blocks (Figure 5). Wherever the centroid of a census block fell within a watershed boundary, the entire population of the census block was included in the total. If the centroid of the census block was outside the boundary, then the population of the entire block was excluded. Using a similar method, the municipal population was estimated by superimposing municipal areas over the map of census blocks.

Table 4. Population Estimates for the Mound Branch Watershed

Municipal Population			Rural Population			Total Population		
1990	**2000**	**2010**	**1990**	**2000**	**2010**	**1990**	**2000**	**2010**
3,542	3,824	3,875	1,063	1,123	1,101	4,605	4,947	4,976

The U.S. Census Bureau estimated the population in the City of Butler to be 4,947 in 2010. Of the 2.14 square mile municipal boundary, approximately 2.05 square miles are within the Mound Branch watershed. Population growth between 1990 and 2010 was approximately 8 percent in the Mound Branch watershed.

Demographic data from the U.S. Census Bureau is included in EPA's web-based EJSCREEN tool and may be used to identify areas in the watershed with potential environmental justice concerns. The EJSCREEN tool is available at https://www.epa.gov/ejscreen. EPA defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to development, implementation, and enforcement of environmental laws, regulations and policies (USEPA 2014a). Communities determined to have environmental justice concerns may qualify for financial and strategic assistance for addressing environmental and public health issues. One example of financial assistance the Department offers that may be available to areas having environmental justice concerns is Section 319 grant funding to address nonpoint source pollution. The Department evaluates 319 grants on a number of criteria, but gives higher priority for selection to proposed projects in disadvantaged communities. Additional grant and financial resource information is available on EPA's environmental justice website at https://www.epa.gov/environmentaljustice.

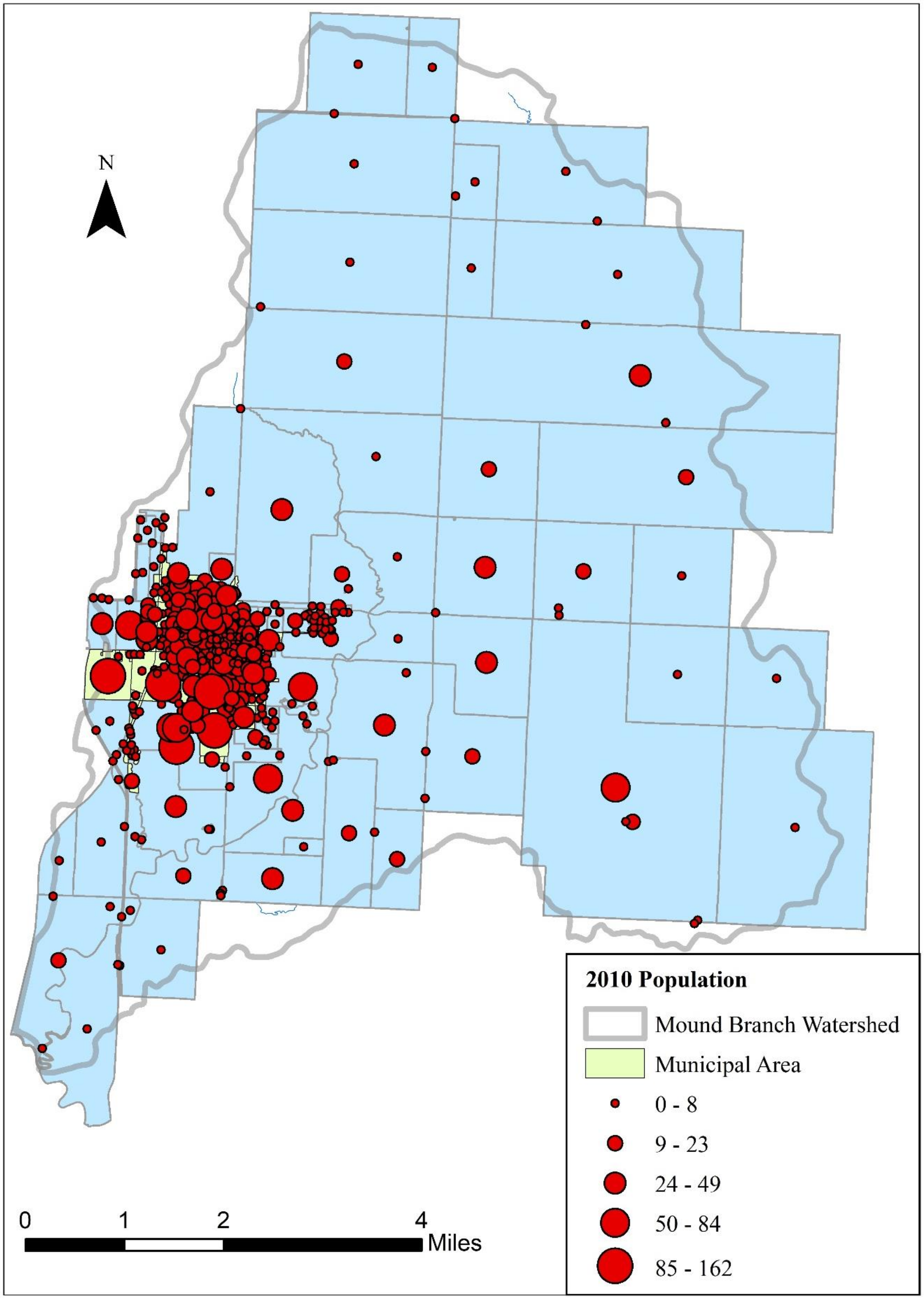

Figure 5. Population Density in the Mound Branch Watershed, 12-digit HUC 102901020504

3.4 Land Cover

A land cover analysis was completed using the 2011 National Land Cover Database (NLCD) published by the U.S. Geological Survey (USGS) (Homer et al. 2015). Land cover area in the Mound Branch watershed is summarized in Table 5 and presented in Figure 6. The total amount of developed area in the Mound Branch watershed is approximately 8.5 percent. Impervious surfaces associated with the developed land cover types ranges from less than 20 percent to greater than 79 percent. Stream degradation associated with impervious surfaces has been shown to first occur at about 10 percent impervious and increases in severity as imperviousness increases (Arnold and Gibbons 1996; Schueler 1994). Hay and pasture land covers 52 percent of the Mound Branch watershed.

Table 5. Land Cover in the Mound Branch Watershed (NLCD, 2011)

Land Cover	Acres	Square Miles	Percent
Barren Land	4.7	0.01	0.01%
Cultivated Crops	9,234.9	14.43	28.19%
Developed, High Intensity	72.9	0.11	0.22%
Developed, Low Intensity	872.5	1.36	2.66%
Developed, Medium Intensity	184.6	0.29	0.56%
Developed, Open Space	1,673.1	2.61	5.11%
Forest	2,956.1	4.62	9.02%
Hay and Pasture	17,045.2	26.63	52.03%
Open Water	203.0	0.32	0.62%
Shrub and Herbaceous	283.3	0.44	0.86%
Wetlands	229.7	0.36	0.70%
Total	32,760.0	51.19	100.00%

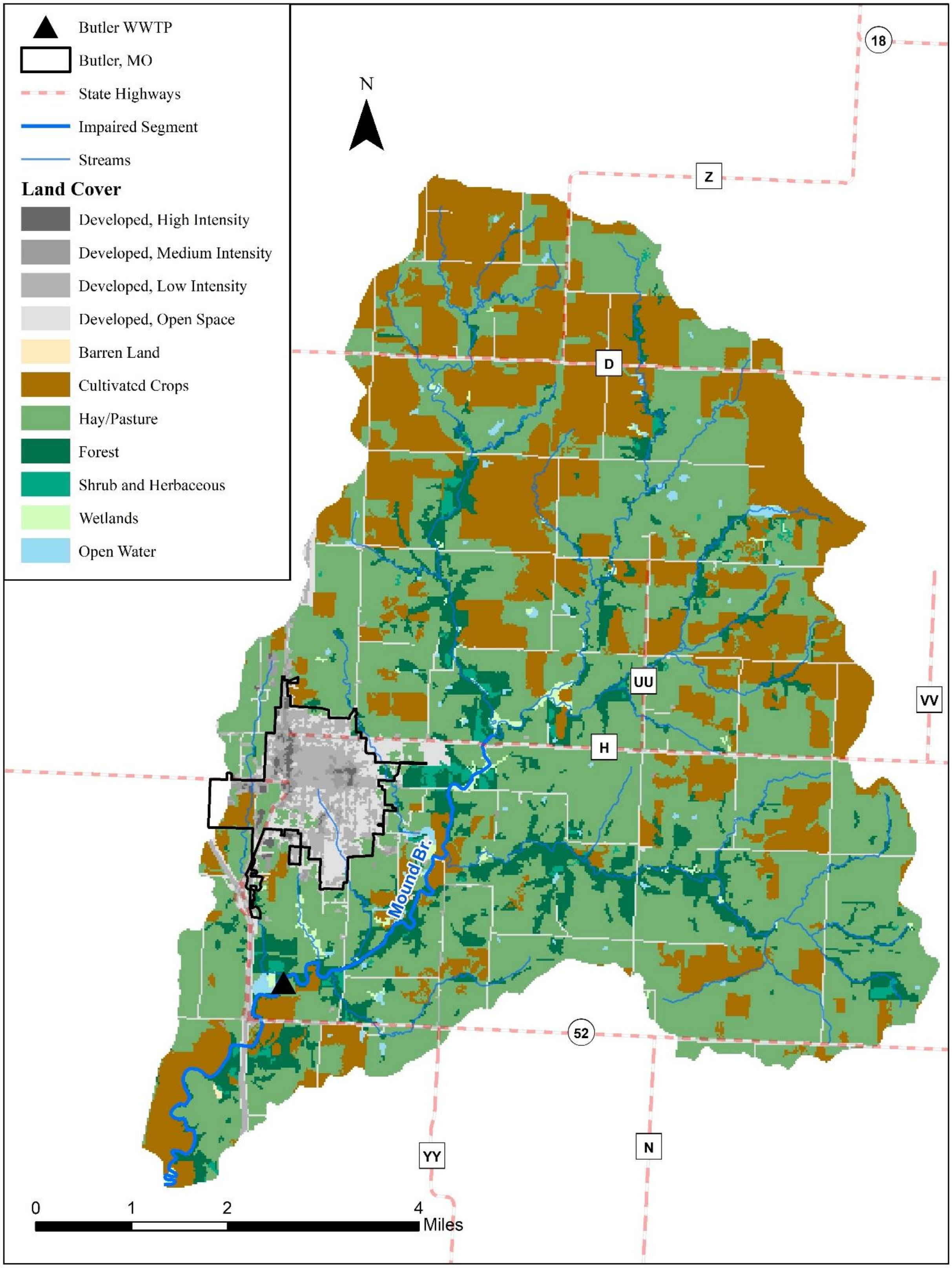

Figure 6. **Land Cover in the Mound Branch Watershed, 12-digit HUC 102901020504**

4. Applicable Water Quality Standards

The purpose of developing a TMDL is to identify the maximum pollutant loading that a water body can assimilate and still attain and maintain water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Water quality standards consist of three major components: designated uses, water quality criteria, and an antidegradation policy.

Per federal regulations at 40 CFR 131.10, the designated uses and criteria to protect those uses assigned to a water body shall provide for the attainment and maintenance of the water quality standards of downstream waters. The components of Missouri's Water Quality Standards discussed in this section meet these requirements and are approved by the EPA. It is not the purview of a TMDL to revise existing water quality standards. In the event that future water quality monitoring demonstrates that water quality standards are not protective of downstream uses, the federal Clean Water Act provides means to address the situation. Such means are described in the EPA's Water Quality Standards Handbook.[6]

4.1 Designated Uses

Designated uses for a water body are defined in Missouri's Water Quality Standards at 10 CSR 20-7.031(1)(C) and assigned per 10 CSR 20-7.031(2) and Table H. These uses must be maintained in accordance with the federal Clean Water Act. The impaired segment of Mound Branch has been assigned the following designated uses:

- Irrigation;
- Livestock and wildlife protection;
- Human health protection;
- Warm water habitat (aquatic life);
- Whole body contact recreation Category B; and
- Secondary contact recreation.

Mound Branch is impaired due to nonattainment of the warm water habitat (aquatic life) use.

4.2 Water Quality Criteria

Water quality criteria are limits on certain chemicals or conditions in a water body to protect particular designated uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements. Missouri 10 CSR 20-7.031(4) and (5) establish General Criteria applicable to all waters of the state at all times and Specific Criteria applicable to waters contained in 10 CSR 20-7.031 Tables G (Lakes) and H (Streams), respectively. Available data and field observations note violations of the specific criterion for minimum dissolved oxygen concentrations in warm water habitats. For streams designated for the protection of aquatic life associated with the warm water habitat use, Table A1 of 10 CSR 20-7.031 specifies a minimum criterion of 5.0 mg/L of dissolved oxygen.

The ultimate endpoint for this revised TMDL is to meet Missouri Water Quality Standards through attainment of the minimum dissolved oxygen criterion of 5.0 mg/L. Compliance with these criteria

[6] https://www.epa.gov/wqs-tech/water-quality-standards-handbook

will be determined in accordance with Department assessment procedures for federal Clean Water Act sections 305(b) and 303(d) reporting.

4.3 Antidegradation Policy

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation, and may be found at 10 CSR 20-7.031(3).

Tier 1 – Protects public health, existing instream water uses, and a level of water quality necessary to maintain and protect existing uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near, or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goal for Mound Branch is to restore water quality to levels that meet the water quality standards.

5. Defining the Problem

Eight water quality monitoring events were conducted in Mound Branch between 1996 and 2015. Water quality studies in 1996 and 1997 indicated the stream had low levels of dissolved oxygen both above and below the Butler Wastewater Treatment Facility. As a result, Mound Branch was listed in Missouri's Section 303(d) List of impaired waters in 1998.

In-stream dissolved oxygen and biochemical oxygen demand are affected by water temperature, the amount of decaying matter (i.e., organic sediment containing nutrients and oxygen consuming substances) in the stream, nutrient transport into streams from overland runoff, turbulence at the air-water interface, and the amount of photosynthesis occurring in plants within the stream. Nutrients (i.e., nitrogen and phosphorus) enter streams from wastewater effluent as well as from stormwater runoff. Benthic algae that adheres to large in-stream substrate can exert an influence on oxygen demand that results in wide daily dissolved oxygen fluctuations. Decaying matter can also accumulate on the bottom of a stream and cause sediment oxygen demand. Sediment oxygen demand is a combination of all of the oxygen-consuming processes that occur at or just below the sediment-water interface. Most of the sediment oxygen demand at the surface of the sediment is due

to the biological decomposition of organic material and the bacterially facilitated nitrification of ammonia-nitrogen (NH_4-N).

Since low dissolved oxygen is an issue upstream of the wastewater treatment plant as well as downstream, addressing the sources of impairment in Mound Branch will require developing nonpoint source, as well as point source, controls in the watershed. However, due to issues regarding low dissolved oxygen in prairie streams, the Department may develop revised dissolved oxygen criteria for Mound Branch and similar streams during future triennial reviews of the water quality standards. Revised dissolved oxygen criteria may better reflect natural stream reaeration conditions to assure that treatment plant effluent limits are based on meeting dissolved oxygen criteria that are naturally occurring. The Department acknowledges that, should revised criteria be developed, a revised Mound Branch TMDL may be necessary. It also acknowledges that the revised criteria may result in no impact for Mound Branch and that new loading calculations may not differ or offer relief from what is currently contained in the Mound Branch TMDL.

The impaired segment of Mound Branch WBID 1300 extends from the confluence with Miami Creek upstream for 10 miles as defined in Table H of Missouri's water quality standards (Figure 1). Water quality data from the impaired segment of Mound Branch that were used in modeling for TMDL development (Section 7) are provided in Table 6. Locations of water quality sampling sites are presented in Figure 7.

Table 6. August 18, 2015 Water Quality Data in the Impaired Segment of Mound Branch*

Site Code	Location	Time	Temp. (°C)	DO (mg/L)	NH_4-N (mg/L)	TKN (mg/L)	NO_3 (mg/L)	TP (mg/L)
	Sample Point 1 (MB-01)							
1300/3.7	Mound Br. 0.1 mi. below Butler WWTF Outfall	6:25	24.0	3.84	0.19	1.77	4.8	1.71
1300/3.7	Mound Br. 0.1 mi. below Butler WWTF Outfall	14:40	24.3	4.13	0.22	1.29	5.09	1.8
	Sample Point 2 (MB-02)							
1300/2.7	Mound Br. 0.9 mi. below Butler WWTF	6:50	23.7	3.75	0.17	2.54	2.15	0.71
1300/2.7	Mound Br. 0.9 mi. below Butler WWTF	14:30	24.1	4.52	0.19	2.36	2.31	0.75
	Sample Point 3 (MB-03)							
1300/1.1	Mound Br. 2.5 mi. below Butler WWTF	7:10	23.7	3.67	0.15	0.79	0.41	0.28
1300/1.1	Mound Br. 2.5 mi. below Butler WWTF	14:10	23.7	4.37	0.12	0.67	0.41	0.27
	Sample Point 4 (MB-04)							
1300/4.8	Mound Branch 1.2 mi. above. Butler WWTF	6:10	24.3	2.04	0.099	0.56	0.058	0.074
1300/4.8	Mound Branch 1.2 mi. above Butler WWTF	15:05	24.1	1.48	0.12	0.64	0.05	0.082
	Butler WWTF Outfall							
-	Effluent grab sample	6:35	24.2	6.8	-	-	-	-
-	Effluent grab sample	14:55	24.1	6.04	-	-	-	-
-	Effluent composite	-	25.4	4.48	0.11	0.92	7.59	2.88

* Temp. = temperature; DO = dissolved oxygen; NH_4-N = ammonia as nitrogen; TKN = total kjeldahl nitrogen; NO_3 = nitrate; TP = total phosphorus; and WWTF = wastewater treatment facility

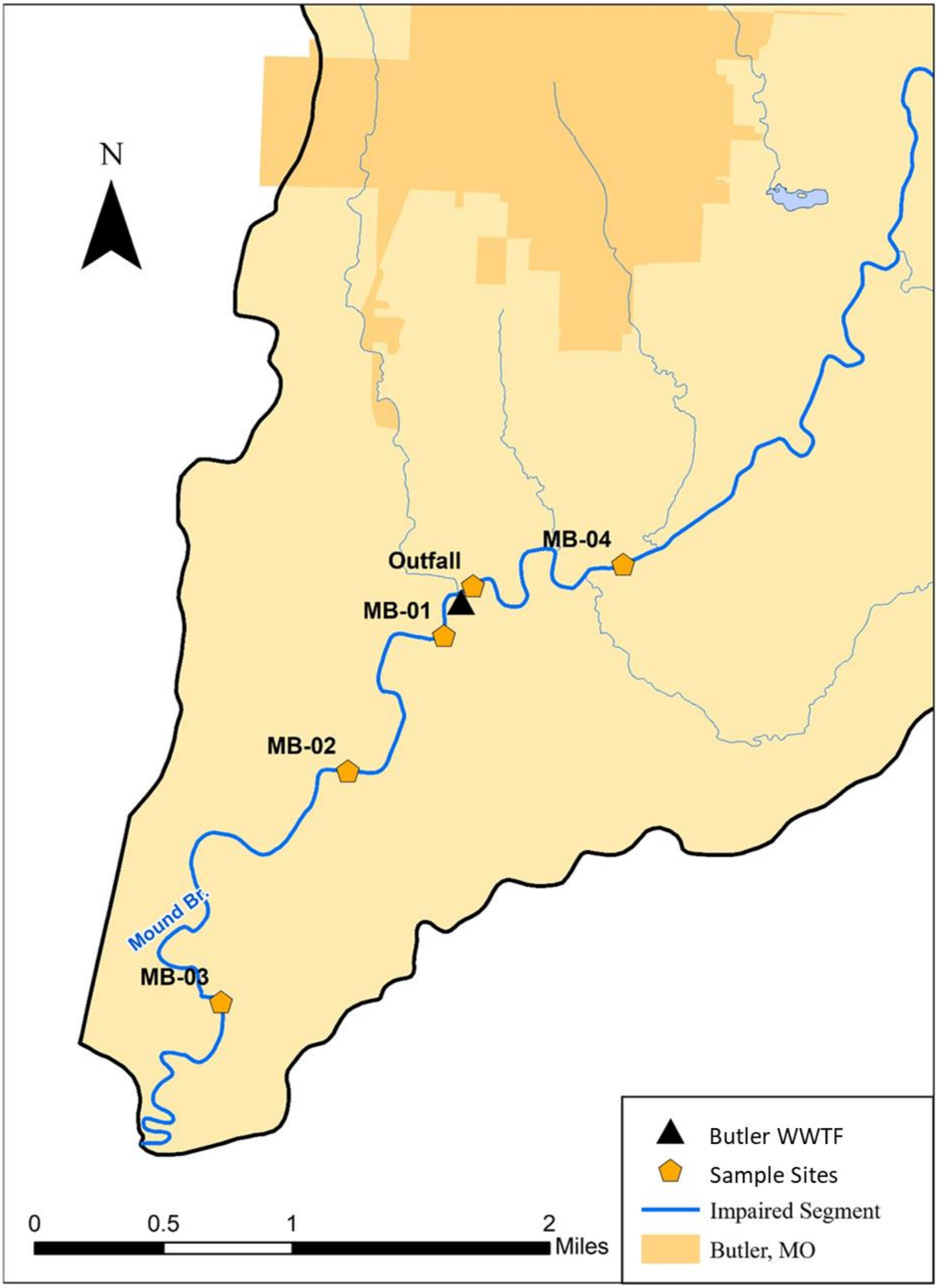

Figure 7. Mound Branch Water Quality Sample Sites

6. Source Inventory and Assessment

Various sources may be contributing pollutant loading to Mound Branch that impacts in-stream dissolved oxygen concentrations. For this reason, a source inventory and assessment is included in this TMDL report to identify and characterize known, suspected, and potential sources of pollutant loading to Mound Branch. These sources are categorized as being either point (regulated) or nonpoint (unregulated).

6.1 Point Sources

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program.[7] Point sources include any discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, or conduit, by which pollutants are transported to a water body. Under this definition, permitted point sources include site-specific permitted municipal and domestic wastewater dischargers, site-specific permitted industrial and non-domestic wastewater dischargers, concentrated animal feeding operations (CAFOs), municipal separate storm sewer systems (MS4s), and general wastewater and stormwater permitted entities. In addition to these permitted sources, illicit straight pipe discharges, which are illegal and therefore unpermitted, are also point sources. As presented in Figure 8, point sources in the Mound Branch watershed include one site-specific municipal and domestic wastewater treatment facility, and seven permitted stormwater outfalls.[8] There are no CAFOs, MS4s, or site-specific permitted industrial or non-domestic dischargers in the Mound Branch watershed.

[7] The Missouri State Operating Permit Program is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program. The NPDES program requires all point sources that discharge pollutants to waters of the United States to obtain a permit. Issued and proposed operating permits are available online at https://dnr.mo.gov/water/business-industry-other-entities/permits-certification-engineering-fees/wastewater.

[8] Heiman Agri Services, MOR240469, a Stormwater permit included in the original 2010 TMDL is no longer operating in the watershed and the permit has been terminated.

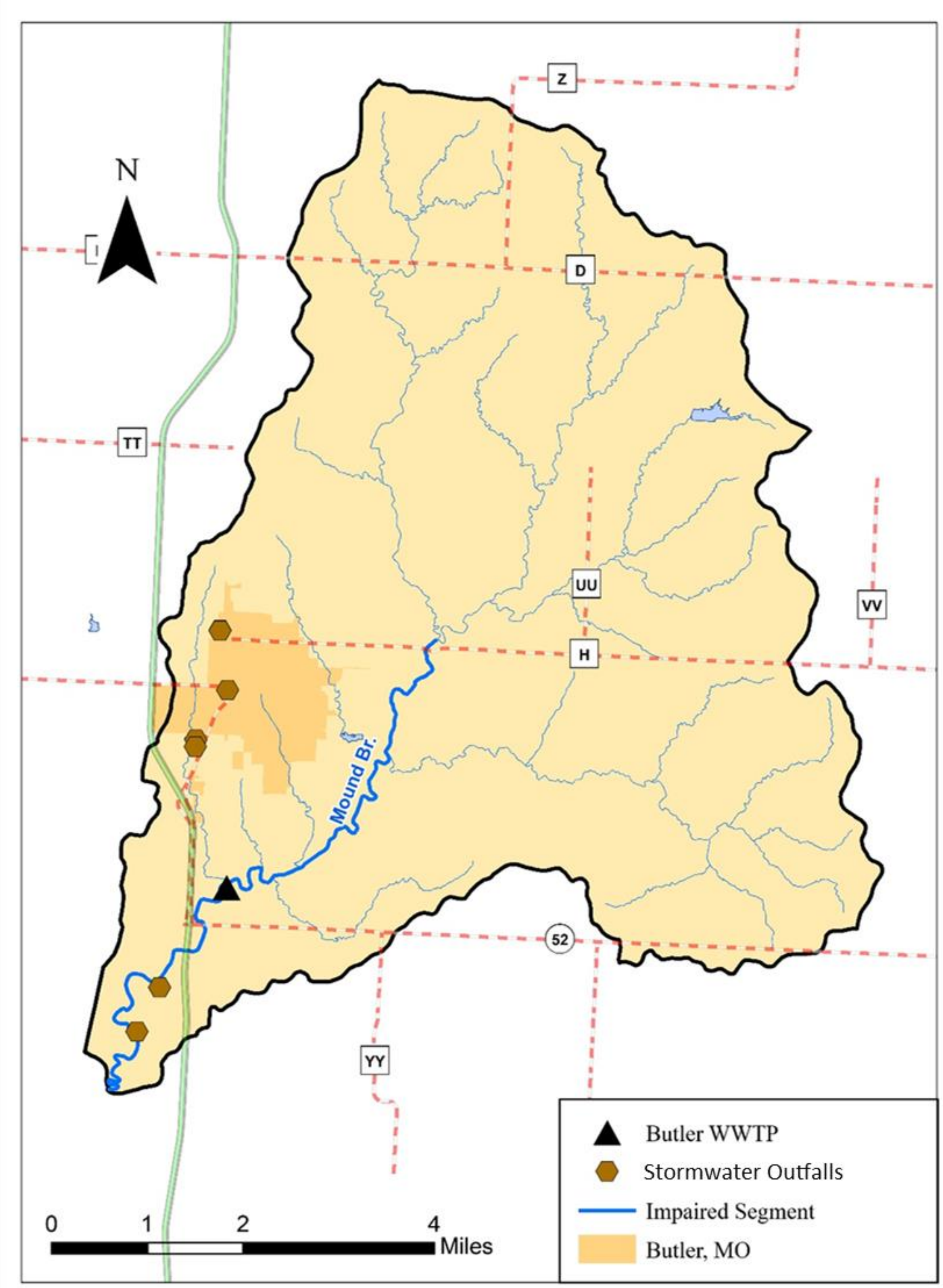

Figure 8. Point Sources in the Mound Branch Watershed

6.1.1 Municipal and Domestic Wastewater Discharge Permits

Dischargers of domestic wastewater include both publicly owned municipal wastewater treatment facilities and private non-municipal treatment facilities. Domestic wastewater is primarily household waste, including graywater and sewage. Untreated or inadequately treated discharges of domestic wastewater can be significant sources of biochemical oxygen demand, nitrogen, and phosphorus to receiving waters. Influences of pollutant loading from domestic dischargers are typically most evident at low-flow conditions when stormwater influences are lower or nonexistent.

The Butler Wastewater Treatment Facility (MO-0096229) is the only municipal wastewater treatment facility in the watershed. This facility has a design flow of 1.5 million gallons per day (MGD). Effluent from the Butler facility discharges directly to the impaired segment of Mound Branch. Water quality sampling and observations on Mound Branch conducted between 1996 and 2015 found low dissolved oxygen conditions. During low flows, effluent from the Butler facility constitutes 99 percent of the flow in Mound Branch.

In addition to the direct discharges from the Butler Wastewater Treatment Facility, potential pollutant contributions may also occur from overflows occurring from the adjoining sanitary sewer system. A sanitary sewer system is a wastewater collection system designed to convey domestic, commercial, and industrial wastewater to the treatment facility. This system can include limited amounts of inflow and infiltration from groundwater and stormwater, but it is not designed to collect large amounts of runoff from precipitation events. Untreated or partially treated discharge from a sanitary sewer system is referred to as a sanitary sewer overflow. Sanitary sewer overflows may result from blockages, line breaks, and sewer defects that allow excess stormwater and groundwater to enter and overload the collection system. In general, sanitary sewer overflows can also result from lapses in sewer operation and maintenance, inadequate sewer design and construction, power failures, and vandalism. Sanitary sewer overflows can occur during either dry or wet weather and at any point in the collection system including overflows from manholes or backups into private residences. Such overflows may discharge directly to nearby waterways, or may be restricted to terrestrial locations. These types of discharges are unauthorized by the federal Clean Water Act, and should remain rare, and be eliminated to the maximum extent possible.

According to a review of sanitary sewer overflow records, the Butler Wastewater Treatment Facility has reported overflows 120 times since 2015. The 120 reported overflows included some high precipitation events and associated stormwater runoff, which flooded manholes. Temporary stormwater inundation events may not contribute to dissolved oxygen impairments in Mound Branch. In accordance with 644.026.1.(15) RSMo and 40 CFR Part 122.41(e), the permittee is required to develop and implement a program for maintenance and repair of collection systems. This requirement is implemented through a special permit condition or schedule of compliance.

6.1.2 Site-Specific Industrial and Non-Domestic Wastewater Permits

Industrial and non-domestic facilities discharge wastewater resulting from non-sewage generating activities. There are no site-specific industrial or non-domestic wastewater permits in the Mound Branch watershed.

6.1.3 CAFO Permits

Concentrated animal feeding operations are animal feeding operations that confine and feed or maintain more than 1,000 animal units for 45 days or more during any 12-month period. Facilities with fewer animal units may be permitted as CAFOs if discharges occur or other water quality issues are discovered per 10 CSR 20-6.300. In Missouri, these types of facilities are permitted with either a site-specific permit or one of two available CAFO general permits. There are no CAFOs in the Mound Branch watershed.

6.1.4 Municipal Separate Storm Sewer System (MS4) Permits

An MS4 is a stormwater conveyance system owned by a public entity that is not a combined sewer or part of a sewage treatment plant. Federal regulations issued in 1990 require discharges from such

systems to be regulated by permits if the population of a municipality, or in some cases a county, is 100,000 or more. In 1999, new federal regulations required permits for discharges from small MS4s that are located within a U.S. Census Bureau defined urban area or have otherwise been designated as needing a permit by the permitting authority. Pollutant loading from these areas would be similar to nonpoint sources occurring through stormwater runoff (e.g., fertilizers from lawns, erosion, and yard debris) and potentially from sanitary sewer overflows entering the system. Although stormwater discharges are often untreated, MS4 permit holders must develop, implement, and enforce stormwater management plans to reduce the contamination of stormwater runoff and prohibit illicit discharges. These plans must include measurable goals, be reported on annually, and meet six minimum control measures. These six minimum control measures are public education and outreach, public participation and involvement, illicit discharge detection and elimination, construction site runoff control, post-construction runoff control, and pollution prevention. There are no applicable MS4 permits in the Mound Branch watershed.

6.1.5 General Wastewater and Non-MS4 Stormwater Permits

General and stormwater permits are issued based on the type of activity occurring and are intended to be flexible enough to allow for ease and speed of issuance, while providing the required protection of water quality. General and stormwater permits are issued for activities similar enough to be covered by a single set of requirements and are designated with permit numbers beginning with “MO-G” or “MO-R,” respectively.

Facilities in the Mound Branch watershed operate under the following General permits, as presented in Table 7:

- MO-G35 Stormwater discharges from facilities with above ground storage capacity of pre-consumer or post-consumer petroleum products totaling more than 20,000 gallons, but less than 250,000 gallons;
- MO-G49 Stormwater and other specified discharges from limestone and other rock quarries, concrete, glass, and asphalt industries;

Table 7. General Permits in the Mound Branch Watershed

Permit No.	Facility Name	Expires
MO-G491371	Loan Oak Quarry	4/30/2022
MO-G350276	MFA Oil Bulk Plant – Butler Bulk Plant	9/17/2022

Facilities in the Mound Branch watershed operating under stormwater permits are presented in Table 8. Permits associated with construction or land disturbance activities (MO-RA) are temporary. The number of effective permits of this type may vary widely in any given year. Despite this variability, final TMDL targets and allocations do not vary as a result of any changes in the numbers of these types of permits.

Table 8. Stormwater Permits in the Mound Branch Watershed

Permit No.	Facility Name	Activity	Expires
MO-R22A022	Southside Lumber Company	Lumber and wood products	9/16/2024
MO-RA14966	Dollar Tree Butler MO	Construction or land disturbance	2/7/2022

For this Revised TMDL, the Department assumes the general and non-MS4 stormwater permits described in Tables 7 and 8, as well as any future general or stormwater permitted activities, will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will be protective of the applicable designated uses within the watershed. For these reasons, general wastewater and stormwater permits are not expected to cause or contribute to the aquatic life impairment of Mound Branch. At any time, if the Department determines that the water quality of streams in the watershed is not being adequately protected, the Department may require the owner or operator of the permitted site to obtain a site-specific operating permit per 10 CSR 20-6.010(13)(C).

6.1.6 Illicit Straight Pipe Discharges

Illicit straight pipe discharges of domestic wastewater are also potential point sources of nutrients and oxygen consuming substances. These types of sewage discharges bypass treatment systems, such as a septic tank or a sanitary sewer, and instead discharge directly to a stream or an adjacent land area (Brown, Caraco and Pitt 2004). Illicit straight pipe discharges are illegal and not authorized under the federal Clean Water Act. At present, there are no data about the presence or number of illicit straight pipe discharges in the Mound Branch watershed. For this reason, it is unknown to what significance straight pipe discharges contribute pollutant loads to Mound Branch. Due to the illegal nature of these discharges, any identified illicit straight pipe discharges must be eliminated

6.2 Nonpoint Sources

Nonpoint source pollution refers to pollution coming from diffuse, non-permitted sources that typically cannot be identified as entering a water body at a single location and include all other categories of pollution not classified as being from a point source. Nonpoint sources are exempt from Department permit regulations per state rules at 10 CSR 20-6.010(1)(B)1. These sources involve stormwater runoff over land and are typically minor or negligible under low-flow conditions. However, sediment and organic material carried into streams during high precipitation events can accumulate in the receiving streambed. Decomposition of these accumulations can contribute to increased oxygen demand during low-flow conditions when water temperatures are warmer and flowing too slowly for adequate reaeration. Runoff from agricultural areas and non-MS4 permitted urban areas, onsite wastewater treatment systems, and areas with poor riparian corridor conditions are typical sources of nonpoint pollutants that contribute to water quality impairments.

6.2.1 Agricultural Runoff

Stormwater runoff and soil erosion from lands used for agricultural purposes (hay and pasture, and cropland) are sources of sediment and nutrient loading. Fertilizer is applied to agricultural lands as chemical forms of nitrogen and phosphorus and as animal manure. Application rates and timing vary by site depending upon a number of factors, including manure quality and soil fertility. Livestock that are not excluded from streams may deposit manure directly into waterways. Operations using nutrient management plans to guide fertilizer applications, employ best management practices to reduce soil erosion, and exclude livestock from streams will contribute smaller nutrient and sediment loads than those that do not.

Approximately 72 percent of soils in the Mound Branch watershed have moderate to high runoff potential at some time of the year, and agricultural areas (cropland and pastureland) account for

about 80 percent of the watershed. Nutrient runoff from agricultural areas may contribute to low dissolved oxygen concentrations upstream of the Butler Wastewater Treatment Facility.

6.2.2 Unregulated Urban Runoff

Urban stormwater that is not regulated through MS4 permits is considered a nonpoint source. Urban stormwater runoff can contain high levels of nitrogen and phosphorus that may result in nutrient loading to streams, which may contribute to excess algae growth and low dissolved oxygen conditions. During low precipitation and critical low flows, nutrients originating from fertilizer placed on residential lawns, cemeteries, parks, and other vegetated areas may be transported into storm sewers via runoff from sprinkler irrigation. Hobbie et al. (2017) found that pet (dog) waste may contribute 76 percent of TP inputs and 28 percent of TN inputs in urban areas. Hobbie et al. (2017) also found that export of phosphorus contributes 32 to 68 percent of storm drain nutrient outputs. Phosphorus transport is especially high in urban areas due to impervious surfaces which inhibit infiltration of soluble phosphorus and the phosphorus-laden runoff is carried to storm drains. In contrast, nitrogen transport is inhibited by up to 83 percent retention in unfertilized parks and storm drain catch basins and pipes. Approximately 8.6 percent of the watershed area is categorized as developed. However, degradation of water quality associated with imperviousness typically occurs in watersheds with at least 10 percent total imperviousness (Arnold and Gibbons 1996; Schueler 1994). For this reason unregulated urban runoff is not expected to be a substantial contributor to the low dissolved oxygen impairment of Mound Branch. However, should substantial development occur in the future, best management practices and low impact development should be considered for mitigating the potential stormwater driven pollutant loading from impervious surfaces in urban areas.

6.2.3 Onsite Wastewater Treatment Systems

Approximately 25 percent of homes in Missouri utilize onsite wastewater treatment systems, particularly in rural areas where public sewer systems may not be available (DHSS 2018). Onsite wastewater treatment systems treat domestic wastewater and disperse it on the property from where it is generated (i.e., a home septic system). When properly designed and maintained, such systems perform well and should not serve as a source of contamination to surface waters. However, onsite wastewater treatment systems can fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface water quality (Horsley and Witten 1996). Failing onsite wastewater treatment systems can contribute nutrient loads and oxygen consuming substances to nearby streams under wet or dry weather conditions through surface runoff and groundwater flows. Onsite wastewater treatment systems may contribute pollutants to waterbodies directly or as component of stormwater runoff.

The exact number of onsite wastewater treatment (septic) systems in the Mound Branch watershed is unknown. EPA's online input data server for the Spreadsheet Tool for Estimating Pollutant Load (STEPL) provides estimates of septic system numbers and population per system by 12-digit HUC watersheds based on 1992 and 1998 data from the National Environmental Service Center (USEPA 2014b).[9] Estimates of septic system numbers for 12-digit HUC 102901020504 are presented in Table 9. The statewide estimated failure rates were estimated from a study by the Electric Power

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[9] The National Environmental Services Center is located at West Virginia University and maintains a clearinghouse for information related to, among other things, onsite wastewater treatment systems. Available URL: www.nesc.wvu.edu/

Research Institute (EPRI 2000). The study suggests that in some areas in Missouri, up to 50 percent of onsite wastewater treatment systems may be failing. Although failing onsite wastewater treatment systems are potential sources of nutrient loading and sediment through overland flow, the significance of such contributions to the impaired segment of Mound Branch is unknown. Due to the location of the impaired segment in relation to the City of Butler, which has an available sewer system and wastewater treatment, onsite wastewater treatment systems are not expected to be a major contributor to the impairment in Mound Branch.

Table 9. STEPL Derived Estimates of Septic System Number in the Mound Branch Watershed

Population per System	Number of Systems	Potential Failure Rates
2	682	30 – 50%

6.2.4 Riparian Corridor Conditions

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal, and assimilation of pollutants in runoff. Therefore, a stream with good riparian cover is often better able to mitigate the impacts of high pollutant loads than a stream with poor or no riparian cover. Shade provided by riparian corridors is also important because it helps to keep water cooler and reduce temperature variation especially during the critical low flows of July and August.

Table 10 presents land cover calculations for the area within 100 feet of all classified segments within the watershed. Agricultural land uses, such as cropland and hay and pasture areas, comprise more than 60 percent of the riparian corridor while forest cover constitutes 30 percent. Forested areas increase detention, removal, and assimilation of nonpoint pollutants and the presence of shade reduces temperature variation throughout the day.

Table 10. Land Cover within 100 feet of the Impaired Segment and Tributaries

Land Cover	Area (acres)	Percent
Developed	168.07	5.05%
Cultivated Crops	498.34	14.98%
Hay and Pasture	1520.92	45.71%
Forest	1004.22	30.18%
Shrub and Herbaceous	25.15	0.76%
Wetlands	110.89	3.33%
Total	3327.58	100.00%

7. Numeric TMDL Targets and Modeling Approach

The pollutant targets in this revised TMDL have been established such that dissolved oxygen concentrations in Mound Branch will meet the minimum criterion of 5.0 mg/L and the warm water habitat (aquatic life) designated use will be restored. Since dissolved oxygen is not a pollutant and cannot be allocated in a TMDL, other numeric targets that will result in attainment of the water quality standards identified in Section 4 of this document have been selected to address the low dissolved oxygen impairment. These targets include TN, TP, biochemical oxygen demand, and ammonia nitrogen. Applicability and support for the selected targets are provided using a QUAL2K model. An additional total suspended solids target is included in this TMDL to address organic loading that may occur from point source discharges, as well as additional nutrient loading from

nonpoint sources. The load duration curve approach was used to calculate acceptable loading and allocations of total suspended solids.

7.1 Organic Sediment and Nutrients

Sediment transported into streams from point sources and nonpoint sources contains nitrogen and phosphorus (nutrients/organic material). In the presence of organic sediment and nutrients, dissolved oxygen in the stream is consumed through biochemical processes of decomposition faster than it can be replenished through atmospheric oxygen exchange and photosynthesis. This results in low dissolved oxygen until the organic matter has decomposed enough that dissolved oxygen replenishment exceeds dissolved oxygen consumption.

7.2 Total Suspended Solids

Total suspended solids are solids that are suspended (i.e., floating) in stream water or wastewater effluent and include both inorganic and organic sediments. Total suspended solids are comprised of both inorganic solids such as gravel and sand, as well as decomposable organic solids such as sewage particulates. Point sources reduce or remove total suspended solids through filtration of effluent, while nonpoint sources reduce total suspended solids through control of sediment erosion using best management practices. Because phosphorus can adhere to soil carried in runoff and organic sediment is a component of total suspended solids, reductions in total suspended solids are expected to result in additional nutrient and organic loading reductions that impact overall instream dissolved oxygen concentrations.

7.3 Biochemical Oxygen Demand

Biochemical oxygen demand is representative of both the quantity of oxygen demanding materials in effluent and the concentration of dissolved oxygen in the receiving stream. Biochemical oxygen demand is composed of carbonaceous biochemical oxygen demand (CBOD) (i.e., the amount of oxygen needed for the microbial utilization of carbon compounds) and nitrogenous biochemical oxygen demand (NBOD) (i.e., the amount of oxygen needed for the microbial oxidation of certain nitrogen compounds). Nitrogenous biochemical oxygen demand is estimated directly from Total Kjeldahl Nitrogen (TKN), which is ammonia nitrogen (NH_4-N) plus organic nitrogen.

7.4 Ammonia as Nitrogen (NH_4-N)

Ammonia nitrogen can influence water quality in natural systems in two ways. The nitrification process in which ammonia nitrogen is reduced to nitrate (NO_3) consumes an estimated 4.2-4.6 grams of oxygen as O_2 per gram of ammonia as NH_4 (Cox 2003). High ammonia nitrogen concentrations in wastewater effluent exert a high oxygen demand (e.g., NBOD) that can contribute to low dissolved oxygen in receiving streams. In addition to depleting oxygen, ammonia can be toxic to aquatic life and must not exceed the concentrations found in Tables B1 and B2 of Missouri's Water Quality Standards. Water quality targets for ammonia nitrogen must be protective of both possible pathways.

7.5 QUAL2K Modeling

QUAL2K is a steady state model based on the Streeter-Phelps equation that estimates the effects of point source biochemical oxygen demand from sewage effluent on receiving stream dissolved oxygen concentrations. QUAL2K simulates the link between dissolved oxygen and biochemical oxygen demand. The QUAL2K model calculates biochemical oxygen demand by using CBOD,

organic nitrogen, and ammonia nitrogen data from the wastewater treatment facility's discharge monitoring report and produces estimates of in-stream dissolved oxygen concentrations.

Two QUAL2K models, a calibration model and a critical condition model, were developed to determine allowable pollutant loading in Mound Branch. For the calibration model, observed data are used to adjust the model to simulate stream characteristics. The calibration model inputs were based on data recorded at three sample points along Mound Branch on August 18, 2015. Data available from this date represent the most recent water quality data from the impaired segment where the time of sampling captured critical low dissolved oxygen conditions. These data are summarized in Table 6.

The critical condition model uses the calibrated stream characteristics to simulate a low-flow critical condition when the Butler Wastewater Treatment Facility is expected to be the predominant source of flow in Mound Branch, and in-stream conditions are most likely to result in low dissolved oxygen conditions. The 2019 QUAL2K critical condition model demonstrates that when wasteload allocations are applied to the Butler Wastewater Treatment Facility, Missouri Water Quality Standards are attained and maintained in the impaired segment. Wasteload allocations result in attainment of the minimum dissolved oxygen criterion under low-flow critical conditions, and are also expected to result in attainment of the minimum dissolved oxygen criterion under other flow conditions when additional reaeration through turbulence and increased pollutant dilution are more likely. Model assumptions, tables of model inputs, and graphical model outputs are provided in Appendix A.

7.6 Total Suspended Solids Load Duration Curve

The load duration curve approach was used to calculate the allowable loading of total suspended solids into Mound Branch. The load duration approach provides a visual representation of stream flow conditions and the pollutant loading that will attain surface water quality targets during those flow conditions. When observed data from the impaired water body is available, the load duration curve approach is also useful in identifying and differentiating between storm-driven and steady-input sources, which can then inform appropriate restoration actions. To develop the total suspended solids load duration curve for Mound Branch, a flow duration curve was developed using a synthetic flow derived from the average daily flow data collected from multiple USGS stream gages in the EDU where Mound Branch is located. For this TMDL, the targeted pollutant loading for total suspended solids is based on the 25th percentile concentration of all USGS total suspended solids data available from Missouri in the EDU for which Mound Branch is located. The concentration target calculated using this approach is 15 mg/L. Additional discussion about the methods used in the modeling and development of the total suspended solids load duration curve for Mound Branch is presented in Appendix B.

8. Calculating Loading Capacity

A TMDL calculates the loading capacity of a water body and allocates that load among the various pollutant sources in the watershed. The loading capacity is the maximum pollutant load that a water body can assimilate and still meet water quality standards. The TMDL is equal to the sum of the wasteload allocations, load allocations, and the margin of safety:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

where LC is the loading capacity, ΣWLA is the sum of the wasteload allocations, ΣLA is the sum of the load allocations, and MOS is the margin of safety.

The following formula is used to convert pollutant concentrations to pounds/day:

(flow in ft^3/sec)(maximum allowable pollutant concentration in mg/L)(5.395*)= pounds/day

*5.395 is the conversion factor used to obtain units of pounds/day.

For this TMDL, the pollutant loading capacity for biochemical oxygen demand, nutrients, and ammonia as nitrogen were calculated at critical low-flow conditions. Critical low-flow conditions are when in-stream conditions are most likely to result in violations of Missouri’s dissolved oxygen criterion due to increased temperature, and limited dilution and flow. The loading capacity of these pollutants is equal to the sum of the nonpoint source load allocation and the sum of wasteload allocations to the Butler Wastewater Treatment Facility. An implicit margin of safety was used for all TMDL calculations as described in Section 11. The pollutant loading capacity and allocations for the impaired segment of Mound Branch during critical and typical (90th percentile) low-flow conditions are presented in Tables 11 and 12 respectively. The loading capacity for total suspended solids was calculated using a load duration curve (Figure 9), and allocations at various flows are presented in Table 13. Additional discussion regarding specific allocations of pollutant loading capacities and margin of safety is provided in Sections 9, 10, and 11.

Table 11. Critical Low Flow TMDL for Mound Branch

Pollutant	Loading Capacity (lbs/day)	∑Wasteload Allocation (lbs/day)	∑Load Allocation (lbs/day)
BOD_5	54.70	54.59	0.11
TP	6.29	6.26	0.03
TN	169.14	169.03	0.11
NH_3-N	12.54	12.52	0.02

Table 12. Typical Low Flow (90 Percent Flow Exceedance) TMDL for Mound Branch

Pollutant	Loading Capacity (lbs/day)	∑Wasteload Allocation (lbs/day)	∑Load Allocation (lbs/day)
BOD_5	59.05	54.59	4.46
TP	7.33	6.26	1.07
TN	173.49	169.03	4.46
NH_3-N	13.32	12.52	0.80

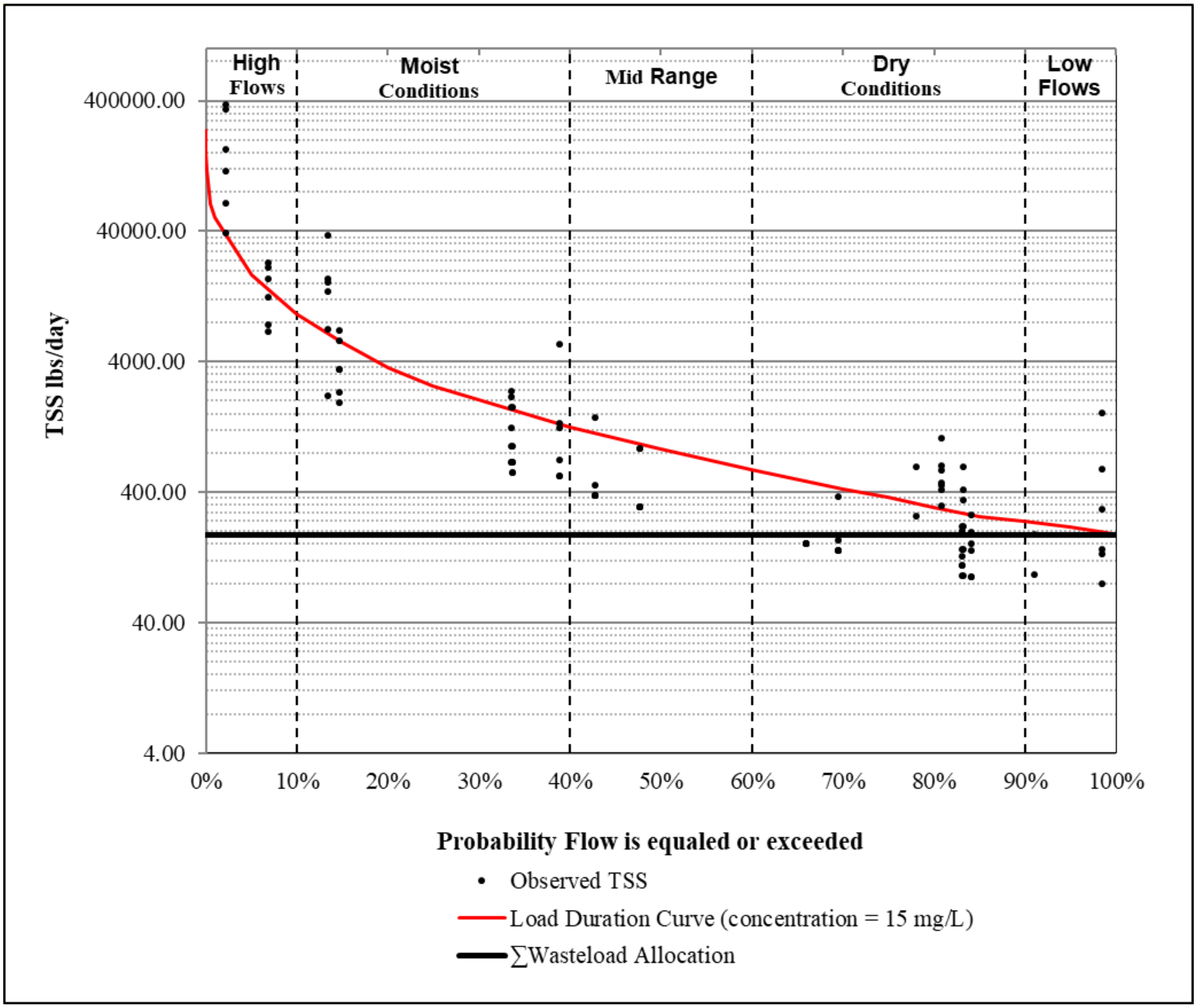

Figure 9. Total Suspended Solids Load Duration Curve for Mound Branch

Table 13. Total Suspended Solids TMDL and Allocations at Various Flows

Percent of time flow equaled or exceeded	Flow (cfs)	Loading Capacity (lbs/day)	∑Wasteload Allocation (lbs/day)	∑Load Allocation (lbs/day)
95	2.68	217.23	187.79	29.44
75	4.49	362.99	187.79	175.20
50	10.49	848.71	187.79	660.93
25	32.41	2623.15	187.79	2435.36
5	228.66	18504.21	187.79	18316.42

9. Wasteload Allocation (Allowable Point Source Load)

The wasteload allocation is the allowable amount of the loading capacity assigned to existing or future point sources. This section discusses the rationale and approach for assigning wasteload allocations to point sources in the Mound Branch watershed as well as considerations given for future sources. Typically, point source permit limits for a given pollutant are the most stringent of either technology-based effluent limits or water quality-based effluent limits. Technology-based effluent limits are based upon the expected capability of a treatment method to reduce the pollutant

to a certain concentration. Water quality-based effluent limits represent the most stringent concentration of a pollutant that a receiving stream can assimilate without violating applicable water quality standards at a specific location. Final effluent limits or other permit conditions must be consistent with the assumptions and requirements of TMDL wasteload allocations per 40 CFR 122.44(d)(1)(vii)(B). Mixing zones and zones of initial dilution are not allowed in regulation for streams with 7Q10 low flows of less than 0.1 cubic feet per second (cfs) [10 CSR 20-7.031(5)(A)4.B.(I)]. The Mound Branch 7Q10 low flow, as estimated at the Butler Wastewater Treatment Facility,[10] is 0.07 cfs. Therefore, in order to ensure attainment of applicable water quality standards in Mound Branch, all water quality targets must be met at end of pipe. The wasteload allocations in this TMDL report do not authorize any facility to discharge pollutants at concentrations that exceed water quality standards.

9.1 Municipal and Domestic Wastewater Discharges

As discussed in Section 6.1.1, the Butler Wastewater Treatment Facility is the only municipal or domestic wastewater discharger in the Mound Branch watershed and at design flow would account for 99 percent of the stream's flow during critical low-flow conditions. The wasteload allocations for the Butler Wastewater Treatment Facility are based on the facility's design flow and appropriate pollutant concentration targets shown by QUAL2K to attain the minimum dissolved oxygen water quality criterion of 5.0 mg/L for the protection of warm water habitat, as well as an additional total suspended solids reference target derived to attain compliance with general criteria associated with organic sediment loading. Wasteload allocations to the Butler Wastewater Treatment Facility are applicable at all flows. In addition to authorized discharges from municipal wastewater treatment facilities, areas serviced by sanitary sewer systems risk nutrient contributions from accidental overflows. As mentioned in Section 6.1.1 of this document, sanitary sewer overflows are unpermitted discharges and not authorized under the federal Clean Water Act. For this reason, sanitary sewer overflows are assigned a wasteload allocation of zero.

Table 14. Wasteload Allocations for Butler Wastewater Treatment Facility (MO-0103331)

Effluent Parameter	Design Flow (MGD)	Existing Permit Limit		WLA at Design Flow		Percent Reduction
		Concentration (mg/L)	Load (lbs/day)	Concentration (mg/L)	Load (lbs/day)	
BOD_5	1.5	Monthly Average = 10	125.2	4.36	54.59	56.4%
TP	1.5	No Existing Limit	No data	0.5	6.26	No data
TN	1.5	No Existing Limit	No data	13.5	169.03	No data
NH_3-N	1.5	Monthly Average = 1.4	17.5	1.0	12.52	28.6%
TSS	1.5	Monthly Average = 15	187.8	15	187.81	0%
DO*	1.5	No Existing Limit	N/A	7.5	N/A	N/A

* Note: For water quality standards to be attained at specified wasteload allocations, Butler WWTF effluent should be maintained to no less than 7.5 mg/L dissolved oxygen.

[10] Per StreamStats: Streamflow Statistics and Spatial Analysis Tools for Water-Resources Applications https://streamstats.usgs.gov/ss/

For point source reductions to achieve the specified loading targets, additional upgrades to the Butler Wastewater Treatment Facility, such as advanced nutrient removal technologies, may be necessary.

9.2 Site-Specific Permitted Industrial and Non-Domestic Wastewater Facilities
There are no site-specific permitted industrial and non-domestic wastewater facilities in the Mound Branch watershed. Therefore, such sources are not assigned a portion of the calculated loading capacity.

9.3 CAFOs
There are no CAFOs in the Mound Branch watershed, thus CAFOs are not assigned a portion of the calculated loading capacity.

9.4 MS4 Permits
There are no MS4 permitted entities in the Mound Branch watershed. Therefore, such sources are not assigned a portion of the calculated loading capacity.

9.5 General Wastewater and Non-MS4 Stormwater Permits
Activities permitted through general or stormwater permits are not expected to contribute significant pollutant loads to surface waters. It is expected that compliance with these types of permits will be protective of the warm water habitat use designated to Mound Branch. For this reason, these types of facilities are not assigned a specified portion of the calculated loading capacity and wasteload allocations are set at existing permit limits and conditions, which are assumed to result in pollutant loading at negligible concentrations that will not exceed the total wasteload allocation.

9.6 Illicit Straight Pipe Discharges
Illicit straight pipe discharges are illegal and are not permitted under the federal Clean Water Act. For this reason, illicit straight pipe discharges are assigned a wasteload allocation of zero. Any existing sources of this type must be eliminated.

9.7 Considerations for Future Point Sources
For this TMDL, no specific portion of the loading capacity is allocated to a reserve capacity. However, the wasteload allocations presented in this TMDL report do not preclude the establishment of future point sources in the watershed. Any future point sources should be evaluated against the TMDL, the range of flows with which any additional loading will affect, and any additional requirements associated with antidegradation. Per federal regulations at 40 CFR 122.4(a), no permit may be issued when the conditions of the permit do not provide for compliance with the applicable requirements of the federal Clean Water Act, or regulations promulgated under the federal Clean Water Act. Additionally, 40 CFR 122.4(i) states no permit may be issued to a new source or new discharger if the discharge from its construction or operation will cause or contribute to violation of water quality standards. Facility types not currently existing in the watershed and not allocated a portion of the loading capacity may be permitted as no discharge facilities as long as permit conditions for land application or other controls maintain potential loading at *de minimis* concentrations. Future general (MO-G) and stormwater (MO-R) permitted activities that operate in full compliance with permit conditions are not expected to contribute pollutant loads above *de*

minimis levels and will not result in loading that exceeds the sum of the TMDL wasteload allocations. Decommissioning of onsite wastewater treatment systems and home connection to a sewerage system for wastewater treatment will result in net pollutant reductions that are consistent with the goals of this TMDL. Wasteload allocations calculated for the Butler Wastewater Treatment Facility are based on design flow instead of actual flow and will account for future discharge increases. Wasteload allocations between point sources may also be appropriately shifted between individual point sources where pollutant loading has shifted as long as the sum of the wasteload allocations is unchanged. In some instances, a potential source may be re-categorized from a nonpoint source to a point source (e.g., newly designated MS4s or other permitted stormwater). If such a source's magnitude, character, and location remain unchanged, then the appropriate portion of the load allocation may be assigned as a wasteload allocation.

10. Load Allocation (Nonpoint Source Load)

The load allocation is the amount of the pollutant load that is assigned to existing and future nonpoint sources, as well as natural background contributions (40 CFR 130.2(g)). Best management practices (BMPs) that reduce erosion and nutrient transport are recommended to reduce pollutant loading from agricultural and urban areas.

The low flow nonpoint source load allocations for nitrogen and phosphorus in Tables 11 and 12 (Section 8) were derived using the streamstats 7Q10, the flow corresponding to the 90 percent flow exceedance from the synthetic flow duration curve, and the QUAL2k derived targets for headwaters. The load allocations in pounds per year are the QUAL2k derived nitrogen and phosphorus concentrations multiplied by the area corrected flows in cfs and a conversion factor of 5.395. Although loading capacity and load allocations are presented only for low flow conditions when the dissolved oxygen impairment is likely to occur, it is expected that nonpoint source pollutant reductions in the watershed will target these concentration targets during all flow conditions. The five day carbonaceous biochemical oxygen demand ($CBOD_5$) and five day biochemical oxygen demand (BOD_5) wasteload allocations are based on the CBOD concentration entered into the QUAL2K model used to determine the wasteload allocations for the Butler Wastewater Treatment Facility using the same flows and conversion factor. Load allocations for total suspended solids (TSS) are the remainder of the TSS loading capacity after allocations to the Butler Wastewater Treatment Facility (Figure 9 and Table 13).

11. Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems (CWA Section 303(d)(l)(C) and 40 C.F.R. 130.7(c)(l)). The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through two approaches:

- Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
- Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

For this TMDL an implicit margin of safety was used. The margin of safety was incorporated into the development of this TMDL by making conservative assumptions in the analysis as follows:

- Wasteload allocation targets were developed at critical conditions when temperatures are highest and dissolved oxygen is naturally low due low reaeration.
- Total suspended solids targets are based on the 25^{th} percentile concentration of all USGS total suspended solids data available from Missouri in the EDU in which Mound Branch is located. Additionally, because phosphorus can adhere to soil carried in runoff and organic sediment is a component of total suspended solids, reductions in total suspended solids are expected to result in additional nutrient and organic loading reductions that impact overall instream dissolved oxygen concentrations.

12. Seasonal Variation

Federal regulations at 40 CFR 130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. This TMDL considered seasonal variation by assuming that the Butler Wastewater Treatment Facility accounts for the majority of the flow in Mound Branch during critical low-flow conditions. Critical low-flow conditions represent the highest stream temperatures and lowest flows, when assimilation of pollutants and reaeration of dissolved oxygen are the most difficult. This likely results in an over-estimate in the winter season when flows from stormwater and snow melt contribute to stream flow volume and dilution at lower temperatures. The Missouri Water Quality Standards account for seasonal variation by establishing ammonia as nitrogen criteria based on pH and temperature such that the criteria are more stringent when water temperatures are higher. In addition, colder water (winter) holds more oxygen, but calculations of loading capacity are based on achieving the dissolved oxygen criterion of 5.0 mg/L during summer low-flow conditions and during the warmest temperatures, which offers the maximum protection for the stream. For total suspended solids, the load duration curve developed for this TMDL represents streamflow under all conditions as it was developed using numerous years of flow data collected during all seasons. For this reason, the total suspended solids targets and allocations found in this TMDL report will be protective of applicable general criteria during all seasons and under all flow conditions.

13. Monitoring Plans

The Department often schedules and carries out post-TMDL monitoring within a reasonable timeframe following completion of permit compliance schedules, facility upgrades, or the implementation of watershed BMPs. The Department will make efforts to conduct field water quality studies that will yield data that represent the normal low flow condition of Mound Branch. Data collected during such monitoring will be used to determine either attainment or continued impairment of water quality standards as part of the biennial water quality assessments required for federal Clean Water Act 305(b) and 303(d) reporting. The data derived from this monitoring may also be used for adjusting pollutant reduction goals and informing implementation activities. Furthermore, the Department will also routinely examine any available quality-assured water quality data collected from Mound Branch by other local, state and federal entities in order to assess the effectiveness of TMDL implementation. In addition, certain quality-assured data collected by universities, municipalities, private companies, and volunteer groups may potentially be considered for monitoring water quality following TMDL implementation.

14. Reasonable Assurance

Section 303(d)(1)(C) of the federal Clean Water Act requires that TMDLs be established at a level necessary to implement applicable water quality standards. As part of the TMDL process, consideration must be given to the assurances that point and nonpoint source allocations will be achieved, and water quality standards attained. Where TMDLs are developed for waters impaired by point sources only, reasonable assurance is provided through the NPDES permitting program. State operating permits requiring effluent and instream monitoring be reported to the Department should provide reasonable assurance that instream water quality standards will be met. The Department regulates point source discharges from the Butler Wastewater Treatment Facility through Missouri State Operating Permit MO-0096229.

Where a TMDL is developed for waters impaired by both point and nonpoint sources, point source wasteload allocations must be stringent enough so that in conjunction with the water body's other loadings (i.e., nonpoint sources) water quality standards are met. Reasonable assurance that nonpoint sources will meet their allocated amount is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls, or best management practices (BMPs) within the watershed. If BMPs or other nonpoint source pollution controls allow for more stringent load allocations, then wasteload allocations can be less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs (40 CFR 130.2(i)). When a demonstration of nonpoint source reasonable assurance is developed for an impaired water body, additional pollutant allocations for point sources may be allowed provided water quality standards are still attained. If a demonstration of nonpoint source reasonable assurance does not exist, or it is determined that nonpoint source pollutant reduction plans, controls, or BMPs are not feasible, durable, or will not result in the required load reductions, then allocation of greater pollutant loading to point sources cannot occur. This TMDL assumes discharge from the Butler Wastewater Treatment Facility is the primary source of flow in Mound Branch during critical low-flow conditions. Therefore, this TMDL does not include wasteload allocations that are less stringent than the water quality targets determined to attain water quality standards.

A variety of grants and loans may be available to assist watershed stakeholders with developing and implementing watershed based plans, controls, and practices to meet the required wasteload and load allocations in the TMDL and demonstrate reasonable assurance. Additionally, cost-share opportunities for implementation of agricultural BMPs are also available. Examples of nonpoint source reduction practices implemented in the Mound Branch watershed between 2016 and 2019 are presented in Table 15. These practices reduce both sediment and nutrient transport into streams by reducing overland runoff and erosion.

Additional information regarding potential funding sources, cost-share opportunities, and implementation actions addressing pollutant sources in the Mound Branch watershed is provided in the supplemental TMDL Implementation Strategies document available online at [dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/tmdls.](dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/tmdls)

Table 15. Nonpoint Source Reduction Practices Implemented in the Mound Branch Watershed

Year	Practice	Sediment and Nutrient Reduction Area (Acres)
2017	Terrace System with Tile	11.1
2017	Stream Protection	26
2018	Grazing System Water Development	184.1
	Sod Waterway	113.7
2019	Sod Waterway	28.6
	Cover Crop	126.5
	Total	490.0

15. Public Participation

EPA regulations at 40 CFR 130.7 require that TMDLs be subject to public review. A 45-day public notice period for this revised TMDL was scheduled from December 3, 2021 through January 18, 2022. The public notice period was extended an additional 15 days to Febrary 2, 2022, due to a request from the City of Butler. The Department will make all comments received during this period and the Department's responses to those comments available online. Groups that directly received notice of the public comment period for this TMDL include, but are not limited to:

- Missouri Clean Water Commission;
- Missouri Water Protection Forum;
- Missouri Department of Conservation;
- County soil and water conservation district;
- Bates County commission;
- Kaysinger Basin Regional Planning Commission;
- University of Missouri Extension;
- Missouri Coalition for the Environment;
- Stream Teams United;
- Stream Team volunteers living in or near the watershed;
- Affected permitted entities; and
- Missouri state legislators representing areas within the watershed.

In addition to those groups contacted directly about the public notice, the Department posted this TMDL and an implementation strategies document online at dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/tmdls.

The Department also maintains an email distribution list for notifying subscribers of significant TMDL updates or activities, including public notices and comment periods. Those interested in subscribing to TMDL updates can submit their email address using the online form available at public.govdelivery.com/accounts/MODNR/subscriber/new?topic_id=MODNR_177.

16. Administrative Record and Supporting Documentation

The Department has an administrative record on file for the revised Mound Branch TMDL. The record contains any plans, studies, data, and calculations on which the TMDL is based. It

additionally includes the public notice announcement, any public comments received, the Department's responses to those comments and files associated with the development of this revised TMDL and the original 2010 TMDL. This information is available upon request to the Department at https://dnr.mo.gov/open-records-sunshine-law-requests. The Department will process any request for information about this TMDL in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the Department's administrative policies and procedures governing Sunshine Law requests.

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Appendix A
Support for QUAL2K Model Assumptions

Existing Condition of Mound Branch

Since the development of the 2010 TMDL, the Butler Wastewater Treatment Facility has implemented improvements designed to aid biological nutrient removal. The facility improvements have resulted in improvements to water quality that have been observed qualitatively through the elimination of algae coverage, discoloration, and offensive odors in Mound Branch downstream of the facility. Department staff did visual inspections along Mound Branch in 2019. At the time of the field visit, water in the creek was murky and the streambed contained clay and silt substrate.

2021 Revised QUAL2K Calibration Model

The revised QUAL2K calibration model includes 7.73 km of Mound Branch, from sample site MB-04 to the confluence with Miami Creek. Reaches were established in the 2021 QUAL2K models as displayed on Figure A-1.

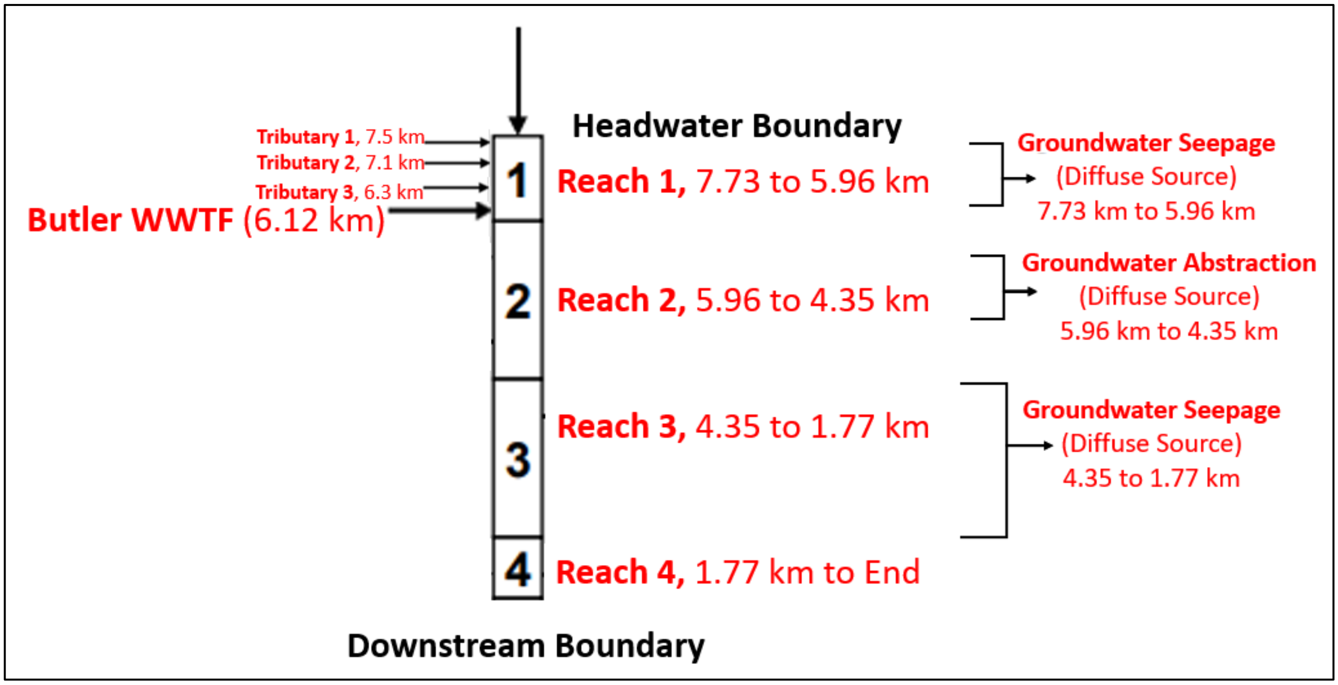

Figure A-1. Mound Branch QUAL2K Reaches

The Revised QUAL2K model was calibrated to Department data recorded on August 18, 2015. The 2015 records are the most recent data where morning low dissolved oxygen concentrations were recorded in addition to afternoon data. These data are presented in Table A-1.

Table A-1. Data Used for the 2021 Revised QUAL2K Calibration Model

Date	Sample Site	Time	Flow (cfs)	TKN (mg/L)	NO3N (mg/L)	NH4N (mg/)	TP (mg/L)	BODu (mg/L)	CBOD5 (mg/L)	DO (mg/L)	pH	Temp (°C)
8/18/2015	MB-01	6:25 AM	0.564	1.77	4.8	0.19	1.71	4.45	<2.0	3.84	7.54	24.0
8/18/2015	MB-01	2:40 PM	-	1.29	5.09	0.22	1.8	-	<2.0	4.13	7.58	24.3
8/18/2015	MB-02	6:50 AM	0.417	2.54	2.15	0.17	0.71	-	<2.0	3.75	7.56	23.7
8/18/2015	MB-02	2:30 PM	-	2.36	2.31	0.19	0.75	-	<2.0	4.52	7.57	24.1
8/18/2015	MB-03	7:10 AM	-	0.79	0.41	0.15	0.28	-	<2.0	3.67	7.55	23.7

8/18/2015	MB-03	2:10 PM	-	0.67	0.41	0.12	0.27	-	<2.0	4.37	7.52	23.7
8/18/2015	MB-04*	6:10 AM	0.003	0.56	0.058	0.099	0.074	3.5	<2.0	2.04	7.54	24.3
8/18/2015	MB-04*	3:05 PM	-	0.64	0.050	0.12	0.082	-	<2.0	1.48	7.45	24.1
8/18/2015	Outfall	6:35 AM	-	-	-	-	-	-	-	6.8	7.82	24.2
8/18/2015	Outfall**	9:20 AM	0.323	0.92	7.59	0.11	2.88	3.19	<2.0	4.48	7.52	25.4
8/18/2015	Outfall	2:55 PM	-	-	-	-	-	-	-	6.04	7.71	24.1

* MB-04 is located upstream of the facility while all other sample points are downstream
** Denotes a composite sample

QUAL2K Headwater input values and data sources are presented in Table A-2. Ultimate biochemical oxygen demand (BOD_u) was analyzed on 3 samples from Mound Branch collected on August 18, 2015. BOD_u values were converted to $CBOD_u$ by dividing by 1.29. In the calibration model, the observed $CBOD_u$ value from sample site MB-04 was used for the Fast CBOD input for the headwater tab and the observed $CBOD_u$ value from the effluent was used for as the Fast CBOD input for the Butler WWTF point source.

Table A-2. QUAL2K Calibration Model Headwater Inputs

Field	**Value**	**Source**
Flow Rate	0.000085 cubic meters per sec.	MB-04 at 3:05 PM
Temperature	24.3 °C 24.1 °C	MB-04 at 6:10 AM MB-04 at 3:05 PM
Conductivity	479.0 umhos 481.0 umhos	MB-04 at 6:10 AM MB-04 at 3:05 PM
Inorganic Solids*	9.25 mg/L	MB-04 median of all data
Dissolved Oxygen	2.04 mg/L 1.48 mg/L	MB-04 at 6:10 AM MB-04 at 3:05 PM
Fast CBOD ultimate	2.71 mgO_2/L	Converted from BOD ultimate at MB-04 at 6:10 AM
Organic Nitrogen**	0.461 mg/L 0.52 mg/L	MB-04 at 6:10 AM MB-04 at 3:05 PM
NH_4-N (ammonia nitrogen)	0.099 mg/L 0.120 mg/L	MB-04 at 6:10 AM MB-04 at 3:05 PM
NO3 Nitrogen	0.058 mg/L am 0.050 mg/L pm	MB-04 at 6:10 AM MB-04 at 3:05 PM
Organic Phosphorus	0.0688 mg/L am (93%) 0.0763 mg/L pm (93%)	MB-04 TP=0.074 mg/L at 6:10 am MB-04 TP=0.082 mg/L at 3:05 pm
Inorganic Phosphorus	0.0052 mg/L am (7%) 0.0057 mg/L pm (7%)	
Phytoplankton (Chlorophyll-a)	10.7 µg/L	MB-04 at 3:05 PM
Detritus (Volatile Suspended Solids)	5.75	MB-04 median of all data
Alkalinity	137.5 $mgCaCO_3/L$	Average of Osage River alkalinity data above Schell City
pH	7.54 am 7.45 pm	MB-04 at 6:10 am MB-04 at 3:05 pm

***Inorganic solids was calculated by subtracting volatile suspended solids from non-filterable residue.
****Organic nitrogen was calculated by subtracting ammonia nitrogen from total kjeldhal nitrogen.

Point Source inputs for the Butler Wastewater Treatment Facility are presented in Table A-3. Diffuse source inputs from groundwater are presented in Table A-4. The inputs used provide the most conservative assumptions, and align the best fit of the QUAL2K model to the observed data. The resulting calibration graphs for dissolved oxygen, ammonia, nitrate, and phosphorus are presented in Figures A-2 through A-5.

Table A-3. QUAL2K Calibration Model Butler WWTF Inputs

Field	Value	Source
Flow Rate	0.0092 cubic meters per second	0.209 MGD observed discharge at outfall
Temperature	24.57°C (+/- 0.65°C)	Average at Outfall
Conductivity	616.30 umhos (+/- 19.50)	Average at Outfall
Dissolved Oxygen	5.77 mg/L (+/- 0.78 mg/L)	Average at Outfall
Fast CBOD ultimate	2.47 mg/L	Ultimate BOD 3.5 / 1.29 (collected at outfall)
Organic Nitrogen	0.81 mg/L	Butler Outfall TKN 0.92 mg/L minus NH4 0.11 mg/L
NH4 Nitrogen	0.11 mg/L	Butler Outfall
NO3 Nitrogen	7.59 mg/L	Butler Outfall
Organic Phosphorus	2.678 mg/L (93%)	Butler Outfall TP=2.88 mg/L
Inorganic Phosphorus	0.2016 mg/L (7%)	
Detritus (Volatile Suspended Solids)	2.5	Median of all available data
Phytoplankton	2.7 µg/L	Chl-a at Butler Outfall
Alkalinity	100.0 $mgCaCO_3/L$	Model default value
pH	7.68 (+/- 0.15)	Average at Butler Outfall

Table A-4. QUAL2K Calibration Model Diffuse Source Inputs

Field	Value	Source
Reach 1 diffuse inflow Reach 2 diffuse abstraction Reach 3 diffuse inflow	0.005 cubic meters per second -0.004 cubic meters per second 0.012 cubic meters per second	Needed to calibrate flow
Temperature	28°C	Aided in calibration of temperature
Conductivity	480 umhos	Average of MB-04 samples
Inorganic Solids	9.25	Average of MB-04 samples
Dissolved Oxygen	3.0 mg/L Reach 1 4.0 mg/L Reach 3	Aided in calibration of DO
Fast CBOD ultimate	3.5 mg/L Reach 1 2.71 mg/L Reach 3	Aided in Fast CBOD calibration Average of MB-04 samples
Organic N	1.5 mg/L Reach 1 0.5 mg/L Reach 3	Aided in calibration of nitrogen
NH4 Nitrogen	0.35 mg/L	Aided in calibration of nitrogen
NO3 Nitrogen	1.0 mg/L Reach 1 0.4 mg/L Reach 3	Aided in calibration of nitrogen
Organic Phosphorus	0.0725 mg/L (93 %)	Average of MB-04 samples TP = 0.078 mg/L
Inorganic Phosphorus	0.0055 mg/L (7%)	
Phytoplankton	10.7 µg/L	MB-04 at 3:05 pm
Detritus (Volatile Suspended Solids)	5.75 mg/L	Median of all data from MB-04
pH	8.0 Reach 1 7.5 Reach 3	Aided in calibration of pH

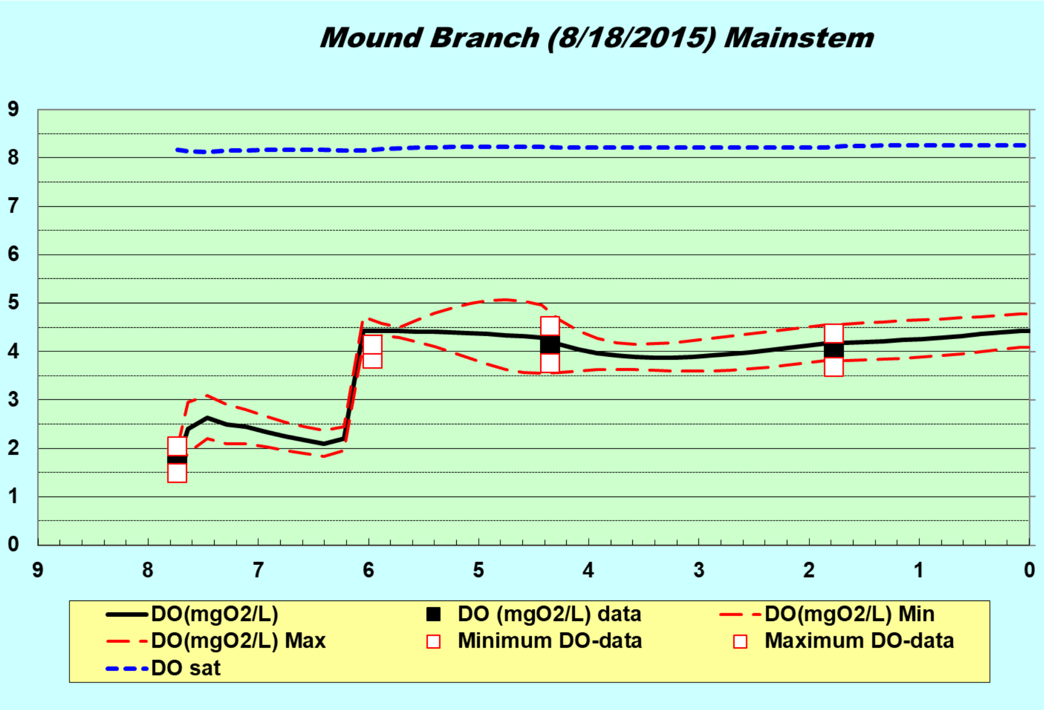

Figure A-2. QUAL2K Calibration Model – Dissolved Oxygen

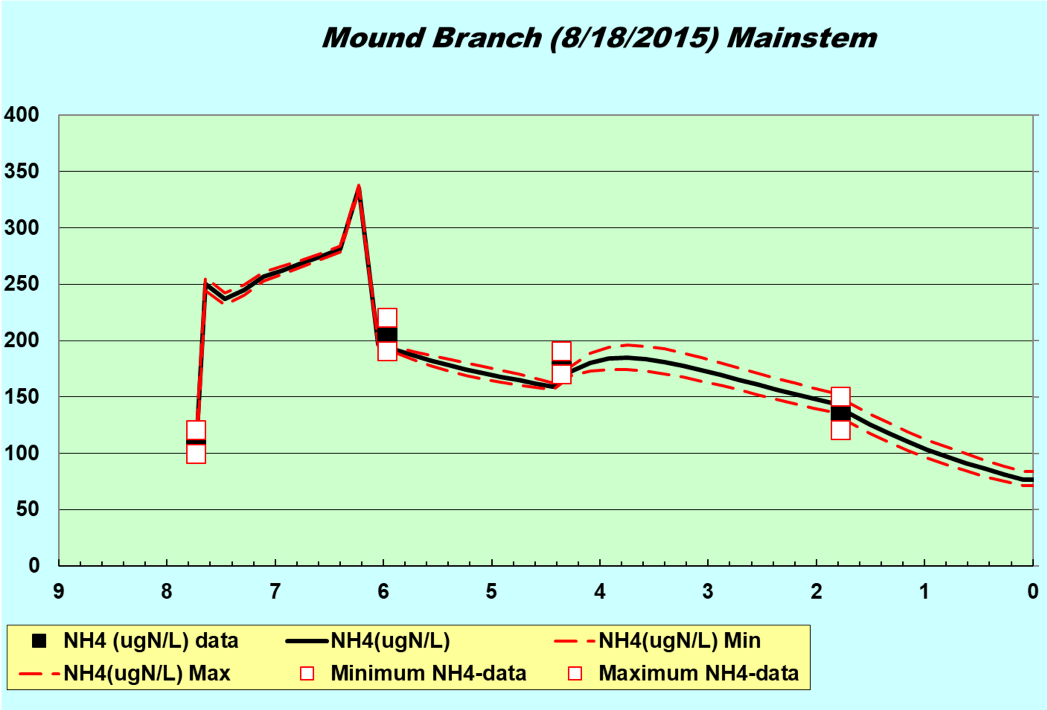

Figure A-3. QUAL2K Calibration Model – Ammonia Nitrogen (NH_4-N)

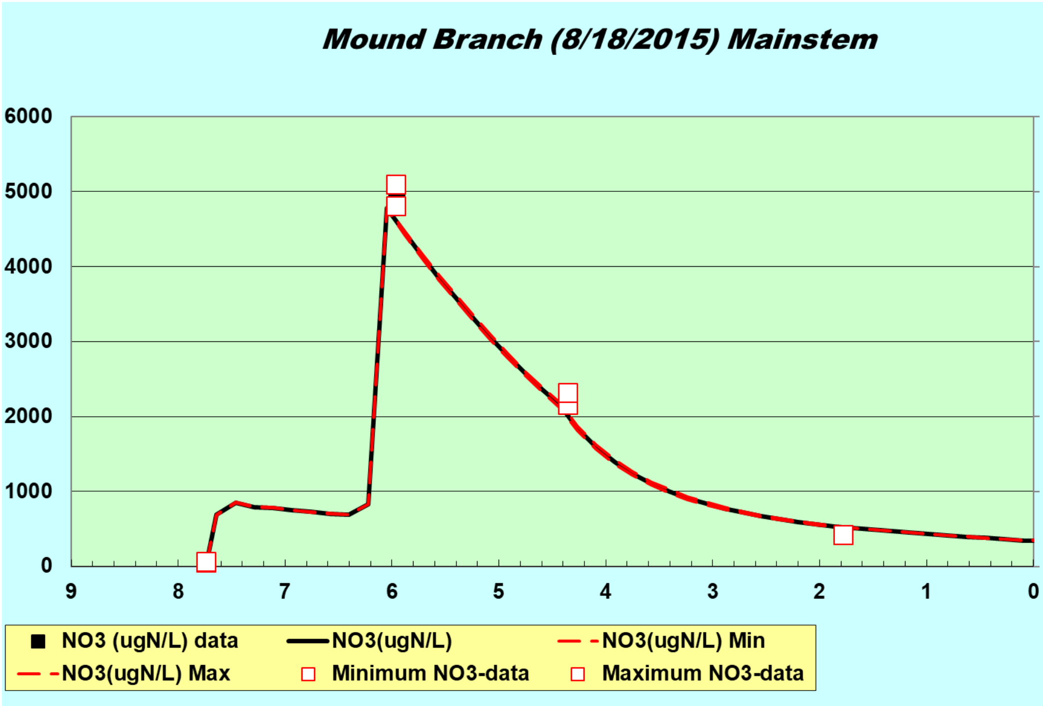

Figure A-4. QUAL2K Calibration Model – Nitrate (NO_3)

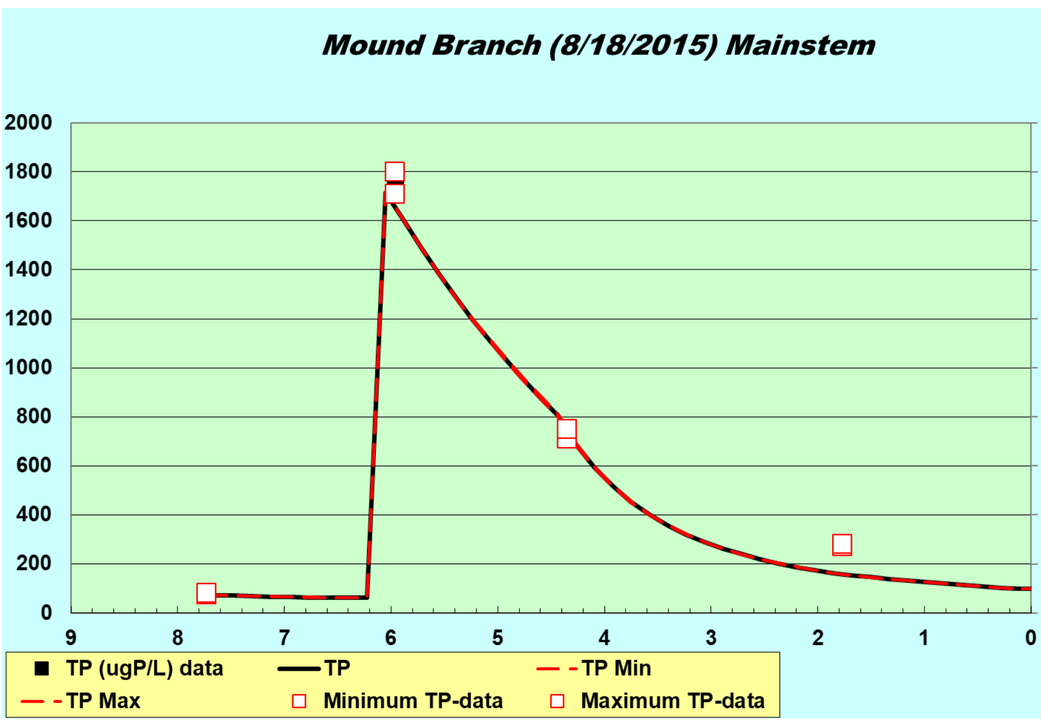

Figure A-5. QUAL2K Calibration Model – Total Phosphorus

Hydraulic Rating Curves

QUAL2K allows rating curves to calculate depth and velocity values from input flow. These rating curves are based on the mathematic relationship between hydraulic parameters in the form $V=aQ^b$ and $H=\alpha Q^\beta$, where V is the average velocity, Q is the flow rate, H is the water level, a/α are coefficients, and b/β are exponents. Adequate depth and velocity data were not available from the August 2015 sampling event. Therefore, regression analysis was used to derive rating curves using observed hydraulic data recorded at sites B1, B3, and B4 on August 4, 2003 and August 16, 2004. These hydraulic data are presented in Table A-5. The resultant coefficients and exponents are shown in Table A-6. The resulting flow, velocity, and depth outputs from the rating curves adequately predicted the trends of observed data and are shown in figures A-6 through A-8.

Table A-5. Observed Hydraulic Data

	August 4, 2003			August 16, 2004		
Site	**Flow (cms)**	**Depth (m)**	**Velocity (m/s)**	**Flow (cms)**	**Depth (m)**	**Velocity (m/s)**
B1	0.002	0.061	0.006	0.012	0.122	0.034
B3	0.030	0.197	0.017	0.023	0.091	0.099
B4	0.017	0.091	0.027	0.027	0.152	0.066

Table A-6. 2019 Calibration Model Rating Curve Coefficients and Exponents

	Velocity		Depth	
Site	**Coefficient a**	**Exponent b**	**Coefficient α**	**Exponent β**
B1	0.0450	0.250	0.8045	0.375
B3	0.5232	0.693	0.2544	0.242
B4	0.5232	0.693	0.2544	0.242

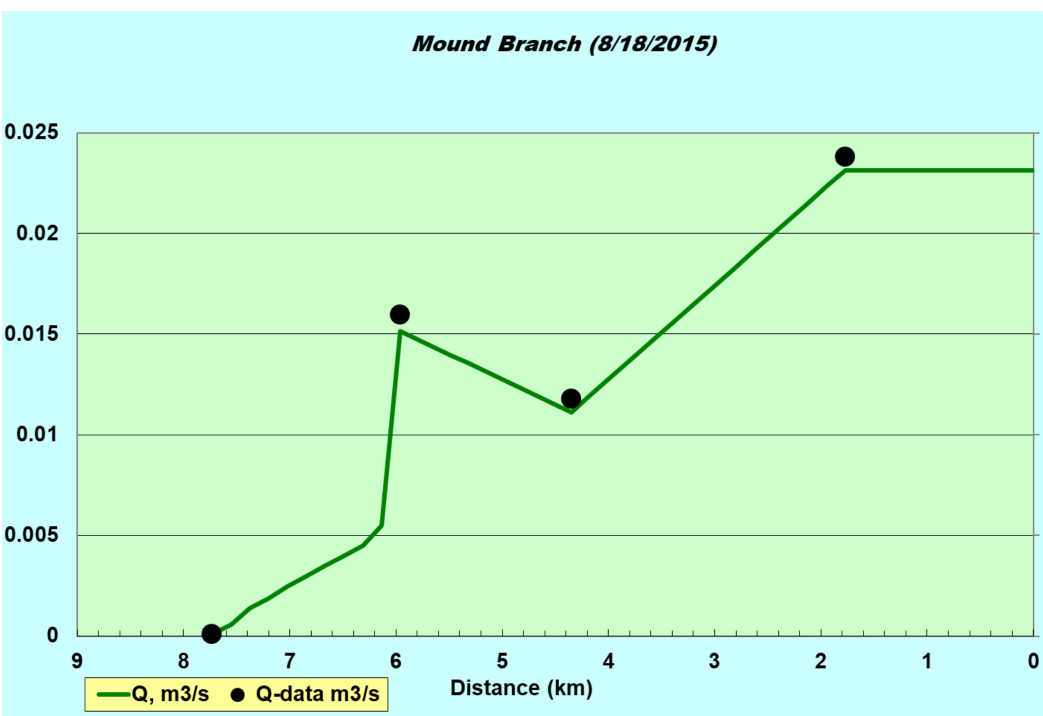

Figure A-6. QUAL2K Rating Curve Model – Flow

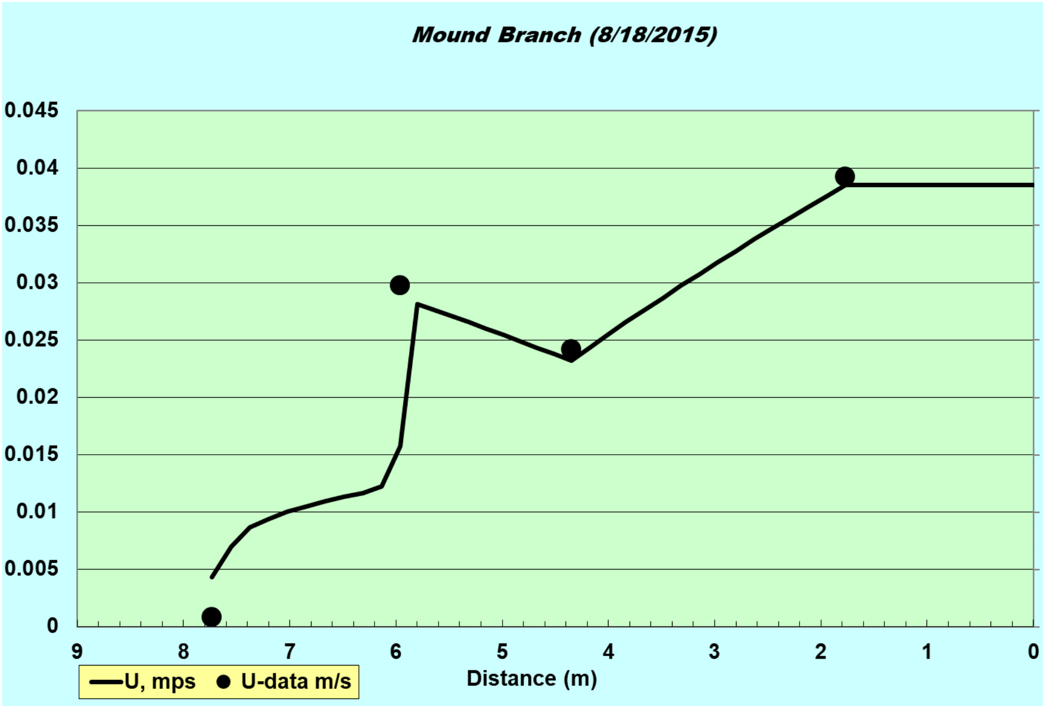

Figure A-7. QUAL2K Rating Curve Model – Velocity

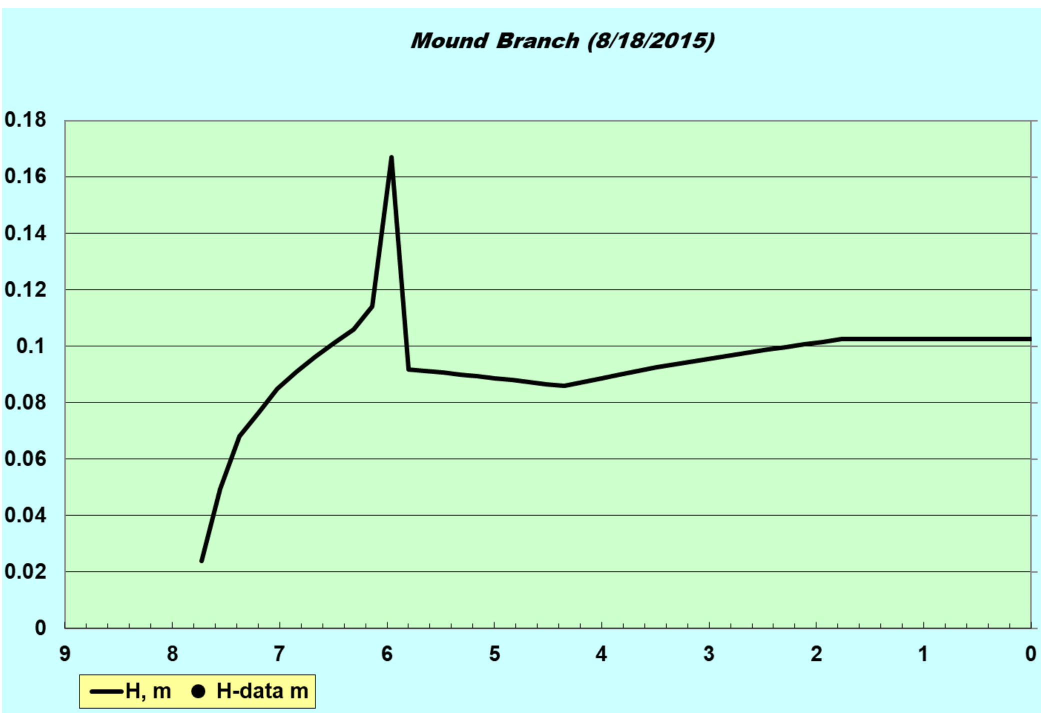

Figure A-8. QUAL2K Rating Curve Model – Depth

2021 TMDL Wasteload Allocation QUAL2K Model During Low-Flow Condition

The rates and formulas assigned to calibrate the QUAL2K model were retained for the wasteload allocation model. The USGS Stream Stats[11] 7Q10 low flow of 0.07 cfs was used as the headwater flow in the Wasteload Allocation Model. Nonpoint source and tributary inputs for nitrogen, phosphorus, fast CBODu, phytoplankton, and detritus were reduced in order to show attainment of the dissolved oxygen criterion upstream of the Butler outfall. The 1.5 MGD design flow was used for the Butler Wastewater Treatment Facility flow Biological oxygen demand (i.e., CBOD and NBOD), nitrogen, and phosphorus values for the Butler Wastewater Treatment Facility were then adjusted until the model demonstrated that in-stream dissolved oxygen would meet or exceed 5.0 mg/L. Specific values input into the wasteload allocation model are presented in Tables A-7 through A-10.

The low-flow WLA model allows CBODult = 7.7 mg/L at the Butler Wastewater Treatment Facility outfall to maintain dissolved oxygen greater than 5.0 mg/L in Mound Branch. The CBODult was converted to $CBOD_5$ using the equation $CBOD_5 = CBOD_{ult} * (1- e^{-kt})$ where k=0.115 and t=5 days. $CBOD_5$ was then converted to BOD_5 using the equation $BOD_5 = CBOD_5 * 1.29$. The final WLA for Butler is BOD_5 = 4.36 mg/L.

$CBOD_{ult}$ = 7.7 mg/L

$CBOD_5 = 7.7 * (1 - e^{(-0.115*5)}) = 3.38$ mg/L

$BOD_5 = 3.38 * 1.29 = 4.36$ mg/L

Table A-7. Input Values for Headwater in the Wasteload Allocation Model

Field	Value	Source
Headwater - Flow Rate	0.00198 cubic meters per second	0.07 cubic feet per second 7Q10 from StreamStats
Temperature	24.3°C am/24.1°C pm	Same as calibration model
Dissolved Oxygen	5.0 mg/L	Missouri WQS criterion
Fast CBOD ultimate	0.50 mgO_2/L	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1
Organic Nitrogen	0.20 mg/L	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1 (TN=0.280 mg/L)
NH4-Nitrogen	0.05 mg/L	
NO3-Nitrogen	0.03 mg/L	
Organic Phosphorus	0.060 mg/L (93%)	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1 (TP=0.067 mg/L)
Inorganic Phosphorus	0.007 mg/L (7%)	
Phytoplankton	1.0 µg/L	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1
Detritus	1.0 mg/L	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1
Alkalinity	137.5 $mgCaCO_3$/L	Same as calibration model
pH	7.54 am 7.45 pm	Same as calibration model

[11] StreamStats: Streamflow Statistics and Spatial Analysis Tools for Water-Resources Applications https://streamstats.usgs.gov/ss/

Table A-8. Input Values for Butler WWTF in the Wasteload Allocation Model

Field	Value	Source
Butler WWTF - Flow Rate	0.0657 cubic meters per second	Facility Design Flow 1.5 MGD
Temperature	24.57°C (+/- 0.65°C)	Same as calibration model
Dissolved Oxygen	7.5 mg/L	Minimum value that will result in stream DO greater than or equal to 5.0 mg/L
Fast CBOD ultimate	7.7 g/L	Maximum value that will result in stream DO greater than or equal to 5.0 mg/L
Organic N	0.5 mg/L	Feasible value that will result in stream DO greater than or equal to 5.0 mg/L
Ammonia Nitrogen	1.0 mg/L	Feasible value that will result in stream DO greater than or equal to 5.0 mg/L
Nitrate + Nitrite	12.0 mg/L	Feasible value that will result in stream DO greater than or equal to 5.0 mg/L
Total Nitrogen	13.5 mg/L	Feasible value that will result in stream DO greater than or equal to 5.0 mg/L
Total Phosphorus	0.5 mg/L	Enhanced Nutrient Removal range
Phytoplankton	2.7 µg/L	Same as calibration model
Alkalinity	100 mg$CaCO_3$/L	Model default value
pH	7.68 (+/- 0.15)	Same as calibration model

Table A-9. Input Values for Diffuse Sources in the Wasteload Allocation Model

Field	Value	Source
Reach 1 diffuse inflow Reach 2 diffuse abstraction Reach 3 diffuse inflow	0.005 -0.004 cubic meters per second 0.012	Same as calibration model
Temperature	28°C	Same as calibration model
Conductivity	480 umhos	Same as calibration model
Inorganic Solids	9.25	Same as calibration model
Dissolved Oxygen	5.0 mg/L	Missouri WQS criterion
Fast CBOD ultimate	0.5 mg/L	Minimum value based on reduction of agricultural runoff
Organic N	0.2 mg/L	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1 (TN=0.280 mg/L)
NH4 Nitrogen	0.050 mg/L	
NO3 Nitrogen	0.030 mg/L	
Organic Phosphorus	0.060 mg/L (93%)	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1 (TP=0.067 mg/L)
Inorganic Phosphorus	0.007 mg/L (7%)	
Phytoplankton	1.0 µg/L	Minimum value based on reduction of agricultural runoff
Detritus	0.5 mg/L	Minimum value based on reduction of agricultural runoff
pH	8.0 Reach 1 7.5 Reach 3	Same as calibration model

Table A-10. Input Values for Tributary Point Sources in Wasteload Allocation Model

Field	Value	Source
Tributary 1 inflow Tributary 2 inflow Tributary 3 inflow	0.0003 0.0001 cubic meters per second 0.0005	Same as calibration model
Temperature	28°C all tributaries	Same as calibration model
Conductivity	480 umhos all tributaries	Same as calibration model
Inorganic Solids	9.25 mg/L all tributaries	Same as calibration model
Dissolved Oxygen	5.0 mg/L all tributaries	Missouri WQS criterion
Fast CBOD ultimate	0.0 ug/L all tributaries	Minimum value based on reduction of agricultural runoff
Organic N	0.2 mg/L all tributaries	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1 (TN=0.280 mg/L)
Ammonia Nitrogen	0.05 mg/L all tributaries	
Nitrate + Nitrite	0.030 mg/L all tributaries	
Organic Phosphorus	0.060 mg/L (93%) all tributaries	Necessary to attain dissolved oxygen standard of 5 mg/L in reach 1 (TP=0.067 mg/L)
Inorganic Phosphorus	0.007 mg/L (7%) all tributaries	
Phytoplankton	1.0 µg/L all tributaries	Minimum value based on reduction of agricultural runoff
Detritus	1.0 mg/L all tributaries	Minimum value based on reduction of agricultural runoff
Alkalinity	137.5 $mgCaCO_3/L$	Same as calibration model
pH	7.5 all tributaries	Same as calibration model

Based on the model inputs presented in the previous sections, the QUAL2K model predicts that dissolved oxygen concentrations will be a minimum of 5.0 mg/L at sample site MB-1 just below the Butler wastewater effluent outlet and at sample sites MB-2 and MB-3 downstream. Consistently limiting the amount of nitrogen and phosphorus that enters the stream is expected to result in reductions of bottom (benthic) algae growth and sediment oxygen demand over time. When combined with a minimum dissolved oxygen content of 7.5 mg/L in the Butler wastewater treatment facility effluent, the model predicts attainment of the dissolved oxygen criterion of 5.0 mg/L downstream of the facility. The graphical QUAL2K wasteload allocation model outputs for dissolved oxygen, nitrogen, and phosphorus are presented in Figures A-9 through A-12.

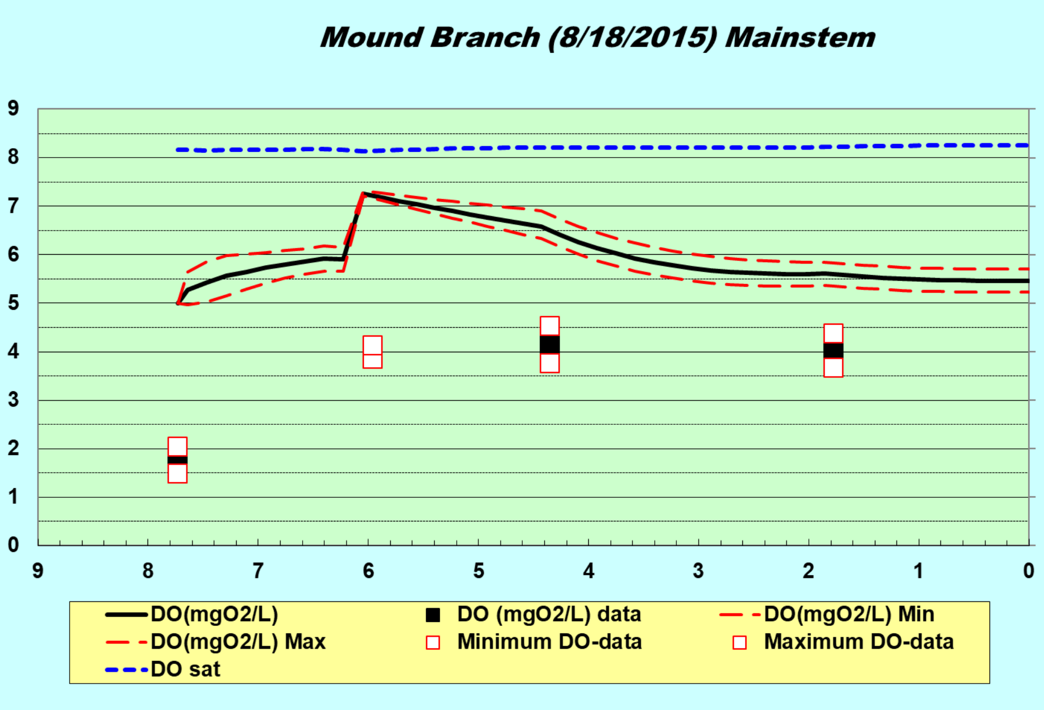

Figure A-9. QUAL2K Wasteload Allocation Model – Dissolved Oxygen

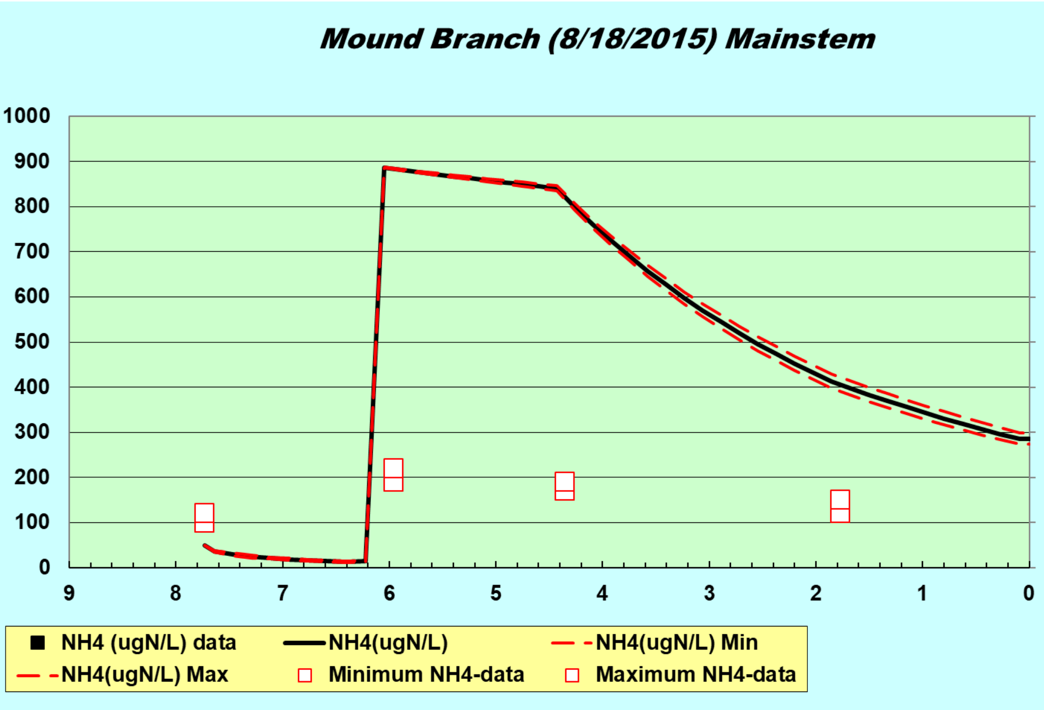

Figure A-10. QUAL2K Wasteload Allocation Model – Ammonia Nitrogen (NH_4-N)

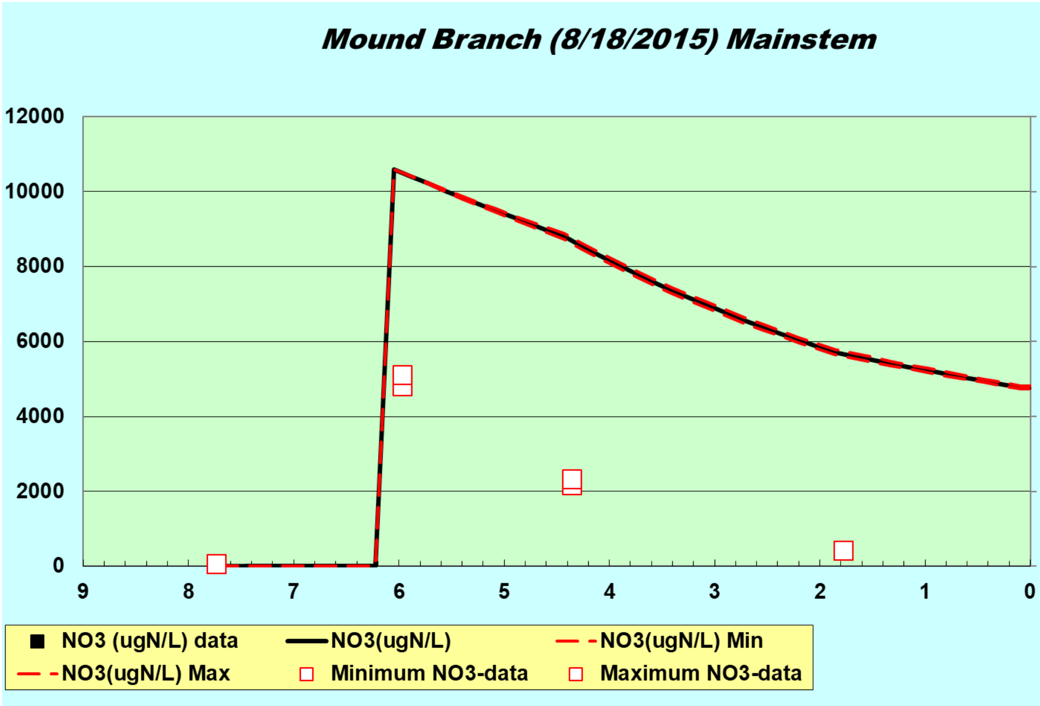

Figure A-11. QUAL2K Wasteload Allocation Model – Nitrate (NO_3)

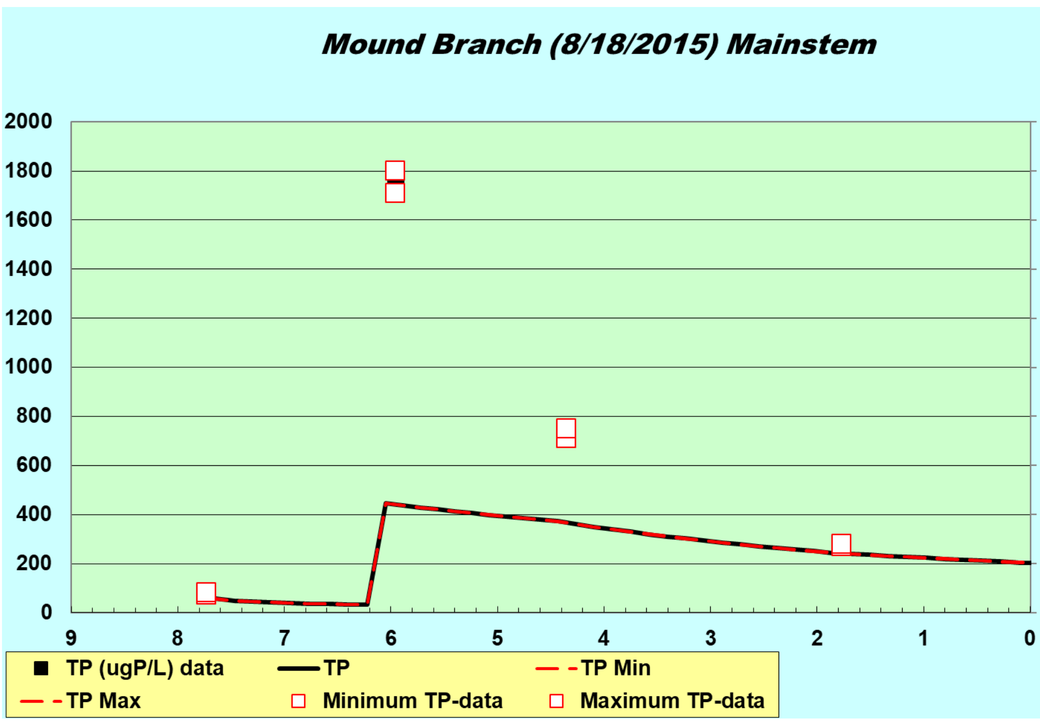

Figure A-12. QUAL2K Wasteload Allocation Model –Total Phosphorus

Appendix B
Total Suspended Solids Load Duration Curve Development

Overview
Load duration curves were used to develop the TSS TMDL for Mound Branch. Load duration curves visually display the loading capacity of a water body at all possible flows based on historic flow data and the defined target concentration for each pollutant. The TSS target for Mound Branch is based on the 25th percentile of all USGS data collected within the South Grand EDU where Mound Branch is located. If the sample value was below the detection limit, then one half of the detection limit was used to calculate the target. Point source wasteloads are established based on the target concentration and the design flows of all regulated facilities that have the potential to contribute pollutants to the water body. The remaining portion of the loading capacity is allocated to nonpoint sources.

Methodology
Load duration curves are based on a flow duration curve developed using a long-term time series of daily flows and a numeric water quality target. The numeric target for the TSS load duration curve is 15 mg/L. Because there are no USGS stream gages on Mound Branch, the load duration curves are based on a flow duration curve derived by synthesizing over 16 years of daily flow data recorded at four USGS stream gages in the South Grand EDU, as presented in Table B-1.

Nash-Sutcliffe statistics are calculated for each gage flow record in order to determine if the relationship is valid for each record. The Nash-Sutcliffe statistic evaluates the efficiency of a predicted (modeled) flow dataset (Nash and Sutcliffe 1970). An efficiency of 1 (100 percent) describes a perfect match, while values less than zero indicate a poor fit of modeled and observed datasets (USGS 2010). This relationship must be valid in order to use the synthesized flow methodology. Model estimates are considered satisfactory if Nash-Sutcliffe statistics are greater than 50 percent (USGS 2013). The flow duration curves for each reference stream and the resulting synthesized flow are depicted in Figure B-1. The synthesized flow duration curve was adjusted to the 51.2 square-mile watershed area of Mound Branch to produce the flow duration curve displayed in Figure B-2.

Because the Mound Branch flow duration curve is based on synthesized stream flows, it does not include additional flow contributed from the Butler Wastewater Treatment Facility, which must be included in order to calculate the TSS TMDL. The TSS TMDL in Section 8 was developed by converting the TSS target of 15 mg/L to pounds per day based on a flow duration curve that includes the additional flow from the Butler Wastewater Treatment Facility and a conversion factor of 5.395. This calculation results in the loading capacity in units of pounds/day.[12] Despite the varying load, the target concentration is constant at all flow percentiles and reflects the static nature of the water quality standards. The observed data provided in Table B-2 are plotted on the load duration curve graphs in Section 8 to demonstrate the magnitude of load reductions that are needed to meet the TSS TMDL and attain water quality standards. The USGS data used to derive the TSS target are provided in Table B-3.

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[12] $Load\ \left(\frac{\text{lbs}}{\text{day}}\right) = [Target(mg/L)] * \left[Flow\ \left(\frac{feet^3}{s}\right)\right] * [Conversion\ Factor]$

Table B-1. Stream Gages Used to Develop the Synthesized Flow[13]

USGS Gage	Drainage Area (mi^2)	Period of Data	Nash-Sutcliff (%)
USGS 6917560 Marmaton River near Richards, MO	455	10/2003-8/2019	99
USGS 6918060 Marmaton River near Nevada, MO	532		93
USGS 6917000 Little Osage River at Fulton, KS	314		87
USGS 6921590 South Grand River at Archie, MO	356		99
		Mean:	**95**

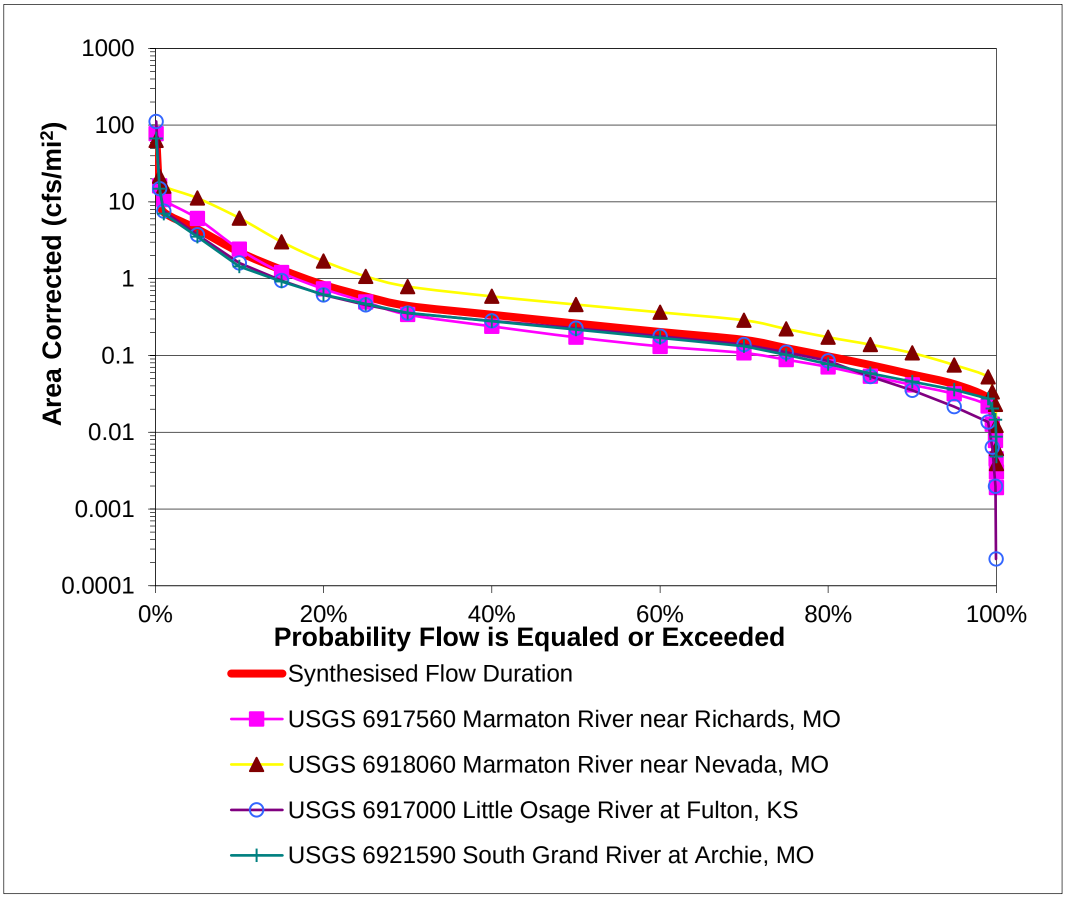

Figure B-1. Area-Based Flow Duration Curves for the South Grand EDU

[13] Flow data that were in provisional status at the time of this report were not used

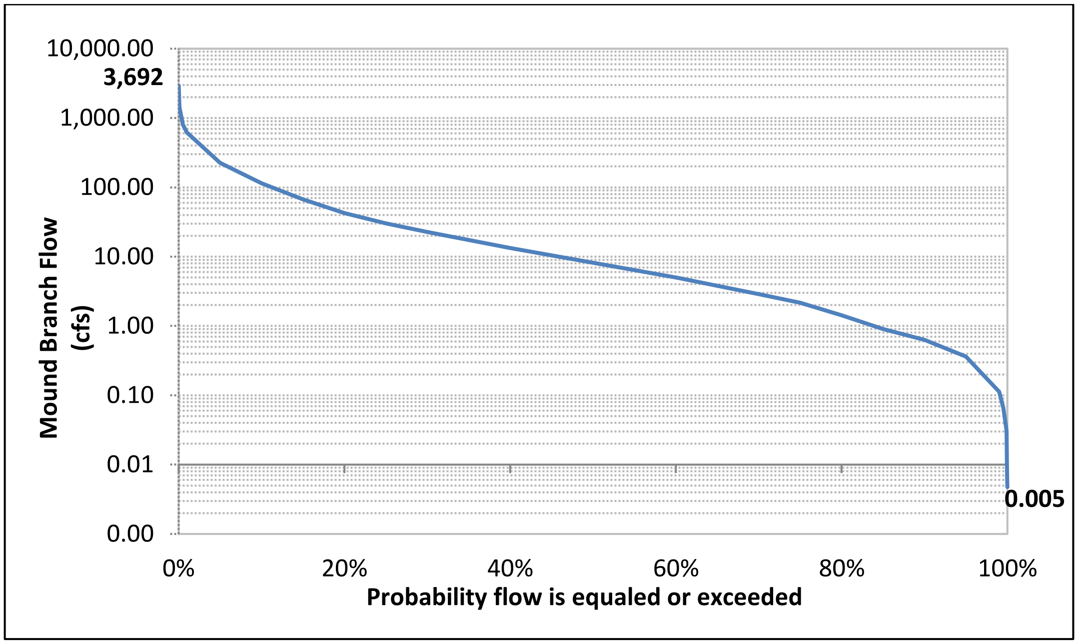

Figure B-2. Flow Duration Curve for Mound Branch

Table B-2. Total Suspended Solids Data for Mound Branch

Site Code	Site Name	Sample Date	Total Suspended Solids (mg/L)
1300/1.1	Mound Br. 2.5 mi.bl. Butler WWTP	8/17/2004	8.0
1300/1.1	Mound Br. 2.5 mi.bl. Butler WWTP	8/17/2004	< 5.0
1300/1.1	Mound Br. 2.5 mi.bl. Butler WWTP	8/17/2004	6.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	8/17/2004	12.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	8/17/2004	11.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	8/17/2004	7.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	8/17/2004	6.0
1300/1.1	Mound Br. 2.5 mi.bl. Butler WWTP	8/18/2004	8.0
1300/1.1	Mound Br. 2.5 mi.bl. Butler WWTP	8/18/2004	< 5.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	8/18/2004	15.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	8/18/2004	11.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	8/18/2004	< 5.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	8/18/2004	9.0
1300/6.9/0.01	Root Branch nr mouth	8/8/2007	29.0
1300/6.91	Mound Branch just ab. Root Br.	8/8/2007	12.0
1300/6.9/0.01	Root Branch nr mouth	9/27/2007	6.0
1300/6.91	Mound Branch just ab. Root Br.	9/27/2007	12.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	12/7/2010	< 5.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	12/7/2010	< 5.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	12/7/2010	< 5.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	12/7/2010	6.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	12/7/2010	13.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	12/7/2010	5.0
1300/8.9	Mound Br. @ Hwy H	12/7/2010	< 5.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	2/14/2011	8.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	2/14/2011	< 5.0

Site Code	Site Name	Sample Date	Total Suspended Solids (mg/L)
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	2/14/2011	5.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	2/14/2011	6.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	2/14/2011	6.0
1300/8.9	Mound Br. @ Hwy H	2/14/2011	16.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	3/9/2011	24.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	3/9/2011	8.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	3/9/2011	22.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	3/9/2011	7.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	3/9/2011	13.0
1300/8.9	Mound Br. @ Hwy H	3/9/2011	18.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	5/10/2011	14.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	5/10/2011	6.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	5/10/2011	15.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	5/10/2011	6.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	5/10/2011	61.0
1300/8.9	Mound Br. @ Hwy H	5/10/2011	8.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	6/13/2011	11.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	6/13/2011	19.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	6/13/2011	21.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	6/13/2011	6.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	6/13/2011	8.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	6/13/2011	16.0
1300/8.9	Mound Br. @ Hwy H	6/13/2011	6.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	7/12/2011	8.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	7/12/2011	12.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	7/12/2011	23.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	7/12/2011	34.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	7/12/2011	19.0
1300/8.9	Mound Br. @ Hwy H	7/12/2011	< 5.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	8/9/2011	32.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	8/9/2011	23.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	8/9/2011	21.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	8/9/2011	24.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	8/9/2011	52.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	8/9/2011	16.0
1300/8.9	Mound Br. @ Hwy H	8/9/2011	30.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	9/13/2011	6.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	9/13/2011	22.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	9/13/2011	11.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	9/13/2011	120.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	9/13/2011	45.0
1300/8.9	Mound Br. @ Hwy H	9/13/2011	10.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	11/8/2011	39.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	11/8/2011	16.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	11/8/2011	31.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	11/8/2011	5.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	11/8/2011	37.0

Site Code	Site Name	Sample Date	Total Suspended Solids (mg/L)
1300/8.9	Mound Br. @ Hwy H	11/8/2011	84.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	12/20/2011	164.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	12/20/2011	17.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	12/20/2011	75.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	12/20/2011	29.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	12/20/2011	51.0
1300/8.9	Mound Br. @ Hwy H	12/20/2011	153.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	1/11/2012	< 5.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	1/11/2012	< 5.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	1/11/2012	< 5.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	1/11/2012	< 5.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	1/11/2012	5.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	1/11/2012	< 5.0
1300/8.9	Mound Br. @ Hwy H	1/11/2012	< 5.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	2/14/2012	< 5.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	2/14/2012	14.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	2/14/2012	14.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	2/14/2012	< 5.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	2/14/2012	< 5.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	2/14/2012	< 5.0
1300/8.9	Mound Br. @ Hwy H	2/14/2012	< 5.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	3/14/2012	18.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	3/14/2012	< 5.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	3/14/2012	15.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	3/14/2012	6.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	3/14/2012	9.0
1300/8.9	Mound Br. @ Hwy H	3/14/2012	9.0
1300/3.0	Mound Br. 0.6 mi.bl. Butler WWTP	4/9/2012	6.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	4/9/2012	< 5.0
1300/3.7/1.2	Trib. Mound Br. @ Outer Rd.	4/9/2012	< 5.0
1300/4.8	Mound Branch 1.2 mi.ab. Butler WWTP	4/9/2012	20.0
1300/6.8/0.9	Trib. to Mound Br. ab. Kennedy Lake	4/9/2012	< 5.0
1300/6.9/1.0	Root Br. 1 mi.ab. Mound Br.	4/9/2012	< 5.0
1300/8.9	Mound Br. @ Hwy H	4/9/2012	< 5.0

Table B-3. Total Suspended Solids Data for the South Grand EDU

Site Name	USGS Station	Date	TSS (mg/L)
Osage R above Schell	6918070	11/29/1994	270
Osage R above Schell	6918070	6/27/1995	140
Osage R above Schell	6918070	8/22/1995	82
Osage R above Schell	6918070	11/7/1995	30
Osage R above Schell	6918070	6/19/1996	480
Osage R above Schell	6918070	11/5/1996	50
Osage R above Schell	6918070	6/24/1997	190
Osage R above Schell	6918070	11/6/1997	31

Site Name	USGS Station	Date	TSS (mg/L)
Osage R above Schell	6918070	6/8/1998	150
Osage R above Schell	6918070	11/2/1998	532
Osage R above Schell	6918070	6/7/1999	195
Osage R above Schell	6918070	11/1/1999	21
Osage R above Schell	6918070	5/22/2000	61
Osage R above Schell	6918070	11/27/2000	11
Osage R above Schell	6918070	11/28/2001	24
Osage R above Schell	6918070	3/11/2002	50
Osage R above Schell	6918070	4/15/2002	183
Osage R above Schell	6918070	5/22/2002	49
Osage R above Schell	6918070	6/17/2002	252
Osage R above Schell	6918070	11/6/2002	13
Osage R above Schell	6918070	3/17/2003	75
Osage R above Schell	6918070	4/15/2003	78
Osage R above Schell	6918070	5/13/2003	426
Osage R above Schell	6918070	6/17/2003	188
Osage R above Schell	6918070	7/9/2003	120
Osage R above Schell	6918070	11/4/2003	32
Osage R above Schell	6918070	3/9/2004	164
Osage R above Schell	6918070	4/19/2004	49
Osage R above Schell	6918070	5/11/2004	62
Osage R above Schell	6918070	6/7/2004	83
Osage R above Schell	6918070	7/21/2004	130
Osage R above Schell	6918070	11/15/2004	109
Osage R above Schell	6918070	3/28/2005	35
Osage R above Schell	6918070	4/12/2005	432
Osage R above Schell	6918070	5/24/2005	256
Osage R above Schell	6918070	6/28/2005	120
Osage R above Schell	6918070	7/25/2005	178
Osage R above Schell	6918070	11/28/2005	23
Osage R above Schell	6918070	3/22/2006	36
Osage R above Schell	6918070	4/19/2006	76
Osage R above Schell	6918070	5/22/2006	172
Osage R above Schell	6918070	6/20/2006	68
Osage R above Schell	6918070	7/24/2006	64
Osage R above Schell	6918070	11/13/2006	18
Osage R above Schell	6918070	2/26/2007	264
Osage R above Schell	6918070	3/6/2007	156
Osage R above Schell	6918070	4/16/2007	560
Osage R above Schell	6918070	5/7/2007	370
Osage R above Schell	6918070	6/26/2007	156

Site Name	USGS Station	Date	TSS (mg/L)
Osage R above Schell	6918070	7/24/2007	448
Osage R above Schell	6918070	11/5/2007	58
Osage R above Schell	6918070	3/17/2008	111
Osage R above Schell	6918070	4/22/2008	108
Osage R above Schell	6918070	5/28/2008	532
Osage R above Schell	6918070	6/3/2008	456
Osage R above Schell	6918070	7/21/2008	50
Osage R above Schell	6918070	10/14/2008	55
Osage R above Schell	6918070	3/17/2009	152
Osage R above Schell	6918070	4/7/2009	96
Osage R above Schell	6918070	5/19/2009	176
Osage R above Schell	6918070	6/2/2009	140
Osage R above Schell	6918070	7/7/2009	107
Osage R above Schell	6918070	10/6/2009	65
Osage R above Schell	6918070	3/9/2010	42
Osage R above Schell	6918070	4/6/2010	92
Osage R above Schell	6918070	5/4/2010	288
Osage R above Schell	6918070	6/2/2010	< 15
Osage R above Schell	6918070	7/7/2010	212
Osage R above Schell	6918070	10/21/2010	41
Osage R above Schell	6918070	3/30/2011	44
Osage R above Schell	6918070	4/20/2011	69
Osage R above Schell	6918070	5/10/2011	29
Osage R above Schell	6918070	6/7/2011	120
Osage R above Schell	6918070	7/26/2011	50
Osage R above Schell	6918070	10/4/2011	37
Osage R above Schell	6918070	3/13/2012	260
Osage R above Schell	6918070	4/3/2012	76
Osage R above Schell	6918070	5/8/2012	126
Osage R above Schell	6918070	6/6/2012	51
Osage R above Schell	6918070	7/10/2012	51
Osage R above Schell	6918070	10/23/2012	68
Osage R above Schell	6918070	3/6/2013	290
Osage R above Schell	6918070	4/2/2013	215
Osage R above Schell	6918070	5/22/2013	410
Osage R above Schell	6918070	6/4/2013	27
Osage R above Schell	6918070	7/16/2013	69
Osage R above Schell	6918070	10/29/2013	22
Osage R above Schell	6918070	3/18/2014	64
Osage R above Schell	6918070	4/8/2014	342
Osage R above Schell	6918070	5/6/2014	54

Site Name	USGS Station	Date	TSS (mg/L)
Osage R above Schell	6918070	6/4/2014	61
Osage R above Schell	6918070	7/8/2014	505
Osage R above Schell	6918070	10/15/2014	360
Osage R above Schell	6918070	3/4/2015	< 30
Osage R above Schell	6918070	4/14/2015	168
Osage R above Schell	6918070	5/19/2015	687
Osage R above Schell	6918070	6/8/2015	239
Osage R above Schell	6918070	7/14/2015	111
Osage R above Schell	6918070	10/6/2015	46
Osage R above Schell	6918070	3/21/2016	21
Osage R above Schell	6918070	4/12/2016	752
Osage R above Schell	6918070	5/11/2016	346
Osage R above Schell	6918070	6/7/2016	119
Osage R above Schell	6918070	7/12/2016	173
Osage R above Schell	6918070	10/25/2016	28
Osage R above Schell	6918070	3/28/2017	44
Osage R above Schell	6918070	4/17/2017	280
Osage R above Schell	6918070	5/9/2017	27
Osage R above Schell	6918070	6/6/2017	69
Osage R above Schell	6918070	7/25/2017	60
Osage R above Schell	6918070	10/24/2017	945
Osage R above Schell	6918070	3/5/2018	67
Osage R above Schell	6918070	3/26/2018	114
Osage R above Schell	6918070	4/10/2018	34
Osage R above Schell	6918070	5/15/2018	72
Osage R above Schell	6918070	6/4/2018	71
Osage R above Schell	6918070	7/16/2018	38
Osage R above Schell	6918070	9/11/2018	293
Osage R above Schell	6918070	10/23/2018	104
Osage R above Schell	6918070	3/11/2019	375
Osage R above Schell	6918070	4/2/2019	208
Osage R above Schell	6918070	5/14/2019	55
Osage R above Schell	6918070	6/4/2019	< 30
Osage R above Schell	6918070	7/29/2019	34
Osage R above Schell	6918070	10/22/2019	174
Osage R above Schell	6918070	5/27/2020	308
Osage R above Schell	6918070	6/22/2020	38
Osage R above Schell	6918070	7/21/2020	61
Osage R above Schell	6918070	10/6/2020	36
Osage R above Schell	6918070	3/23/2021	< 30
Osage R above Schell	6918070	7/26/2021	96

Site Name	USGS Station	Date	TSS (mg/L)
Osage R above Schell	6918070	8/24/2021	150
Osage R above Schell	6918070	11/3/2021	74
Osage R above Schell	6918070	3/8/2022	84
Cedar Creek near Pleasant View, MO	6919500	10/14/2008	< 15
Cedar Creek near Pleasant View, MO	6919500	11/3/2008	< 15
Cedar Creek near Pleasant View, MO	6919500	12/1/2008	< 15
Cedar Creek near Pleasant View, MO	6919500	1/26/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	2/3/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	3/17/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	4/7/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	5/19/2009	< 30
Cedar Creek near Pleasant View, MO	6919500	6/2/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	7/7/2009	23
Cedar Creek near Pleasant View, MO	6919500	8/18/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	9/1/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	10/6/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	11/2/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	12/7/2009	< 15
Cedar Creek near Pleasant View, MO	6919500	1/20/2010	< 15
Cedar Creek near Pleasant View, MO	6919500	2/1/2010	< 15
Cedar Creek near Pleasant View, MO	6919500	3/9/2010	< 15
Cedar Creek near Pleasant View, MO	6919500	4/6/2010	< 15
Cedar Creek near Pleasant View, MO	6919500	5/4/2010	19
Cedar Creek near Pleasant View, MO	6919500	6/2/2010	< 15
Cedar Creek near Pleasant View, MO	6919500	7/7/2010	22
Cedar Creek near Pleasant View, MO	6919500	8/3/2010	18
Cedar Creek near Pleasant View, MO	6919500	9/2/2010	86
Cedar Creek near Pleasant View, MO	6919500	10/13/2010	< 15
Cedar Creek near Pleasant View, MO	6919500	11/9/2010	< 15
Cedar Creek near Pleasant View, MO	6919500	12/1/2010	< 15
Cedar Creek near Pleasant View, MO	6919500	1/13/2011	< 15
Cedar Creek near Pleasant View, MO	6919500	2/7/2011	< 15
Cedar Creek near Pleasant View, MO	6919500	3/30/2011	< 15
Cedar Creek near Pleasant View, MO	6919500	4/20/2011	23
Cedar Creek near Pleasant View, MO	6919500	5/10/2011	16
Cedar Creek near Pleasant View, MO	6919500	6/7/2011	< 15
Cedar Creek near Pleasant View, MO	6919500	7/26/2011	< 15
Cedar Creek near Pleasant View, MO	6919500	8/9/2011	< 30
Cedar Creek near Pleasant View, MO	6919500	9/7/2011	23
Cedar Creek near Pleasant View, MO	6919500	10/4/2011	< 15
Cedar Creek near Pleasant View, MO	6919500	11/1/2011	< 15

Site Name	USGS Station	Date	TSS (mg/L)
Cedar Creek near Pleasant View, MO	6919500	12/5/2011	16
Cedar Creek near Pleasant View, MO	6919500	1/18/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	2/15/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	3/14/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	4/3/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	5/8/2012	120
Cedar Creek near Pleasant View, MO	6919500	6/6/2012	18
Cedar Creek near Pleasant View, MO	6919500	7/10/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	9/5/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	9/12/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	10/23/2012	< 30
Cedar Creek near Pleasant View, MO	6919500	11/13/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	12/5/2012	< 15
Cedar Creek near Pleasant View, MO	6919500	1/15/2013	< 15
Cedar Creek near Pleasant View, MO	6919500	2/4/2013	< 15
Cedar Creek near Pleasant View, MO	6919500	3/7/2013	< 15
Cedar Creek near Pleasant View, MO	6919500	4/2/2013	26
Cedar Creek near Pleasant View, MO	6919500	5/22/2013	124
Cedar Creek near Pleasant View, MO	6919500	6/4/2013	26
Cedar Creek near Pleasant View, MO	6919500	7/16/2013	< 15
Cedar Creek near Pleasant View, MO	6919500	8/19/2013	< 15
Cedar Creek near Pleasant View, MO	6919500	9/3/2013	< 15
Cedar Creek near Pleasant View, MO	6919500	10/29/2013	46
Cedar Creek near Pleasant View, MO	6919500	11/5/2013	< 15
Cedar Creek near Pleasant View, MO	6919500	12/2/2013	< 30
Cedar Creek near Pleasant View, MO	6919500	1/13/2014	66
Cedar Creek near Pleasant View, MO	6919500	2/10/2014	< 15
Cedar Creek near Pleasant View, MO	6919500	3/18/2014	18
Cedar Creek near Pleasant View, MO	6919500	4/8/2014	< 15
Cedar Creek near Pleasant View, MO	6919500	5/6/2014	46
Cedar Creek near Pleasant View, MO	6919500	6/4/2014	29
Cedar Creek near Pleasant View, MO	6919500	7/8/2014	90
Cedar Creek near Pleasant View, MO	6919500	8/6/2014	< 15
Cedar Creek near Pleasant View, MO	6919500	9/3/2014	29
South Grand River at Archie, MO	6921590	6/14/2007	22
South Grand River at Archie, MO	6921590	7/13/2007	30
South Grand River at Archie, MO	6921590	9/13/2007	12
South Grand River at Archie, MO	6921590	11/30/2007	< 10
South Grand River at Archie, MO	6921590	1/17/2008	15
South Grand River at Archie, MO	6921590	3/20/2008	128
South Grand River at Archie, MO	6921590	5/14/2008	180

Site Name	USGS Station	Date	TSS (mg/L)
South Grand River at Archie, MO	6921590	7/23/2008	17
South Grand River at Archie, MO	6921590	9/11/2008	27
South Grand River at Archie, MO	6921590	10/9/2008	< 15
South Grand River at Archie, MO	6921590	1/6/2009	< 15
South Grand River at Archie, MO	6921590	3/27/2009	130
South Grand River at Archie, MO	6921590	5/19/2009	40
South Grand River at Archie, MO	6921590	7/8/2009	27
South Grand River at Archie, MO	6921590	9/23/2009	75
South Grand River at Archie, MO	6921590	10/27/2009	91
South Grand River at Archie, MO	6921590	1/21/2010	210
South Grand River at Archie, MO	6921590	3/10/2010	36
South Grand River at Archie, MO	6921590	5/27/2010	402
South Grand River at Archie, MO	6921590	7/22/2010	178
South Grand River at Archie, MO	6921590	9/8/2010	18
South Grand River at Archie, MO	6921590	10/28/2010	< 15
South Grand River at Archie, MO	6921590	1/25/2011	< 15
South Grand River at Archie, MO	6921590	3/10/2011	70
South Grand River at Archie, MO	6921590	5/10/2011	52
South Grand River at Archie, MO	6921590	7/29/2011	< 30
South Grand River at Archie, MO	6921590	9/20/2011	46
South Grand River at Archie, MO	6921590	10/26/2011	< 15
South Grand River at Archie, MO	6921590	1/18/2012	< 15
South Grand River at Archie, MO	6921590	3/16/2012	52
South Grand River at Archie, MO	6921590	5/14/2012	36
South Grand River at Archie, MO	6921590	9/25/2012	18
South Grand River at Archie, MO	6921590	10/23/2012	< 15
South Grand River at Archie, MO	6921590	1/10/2013	< 15
South Grand River at Archie, MO	6921590	3/25/2013	< 15
South Grand River at Archie, MO	6921590	5/17/2013	26
South Grand River at Archie, MO	6921590	7/23/2013	27
South Grand River at Archie, MO	6921590	9/3/2013	23
South Grand River at Archie, MO	6921590	10/30/2013	19
South Grand River at Archie, MO	6921590	1/9/2014	< 15
South Grand River at Archie, MO	6921590	3/28/2014	23
South Grand River at Archie, MO	6921590	5/16/2014	50
South Grand River at Archie, MO	6921590	7/28/2014	27
South Grand River at Archie, MO	6921590	9/19/2014	147
South Grand River at Archie, MO	6921590	10/31/2014	< 15
South Grand River at Archie, MO	6921590	1/22/2015	< 15
South Grand River at Archie, MO	6921590	3/3/2015	< 15
South Grand River at Archie, MO	6921590	5/18/2015	282

Site Name	USGS Station	Date	TSS (mg/L)
South Grand River at Archie, MO	6921590	7/20/2015	56
South Grand River at Archie, MO	6921590	9/24/2015	55
South Grand River at Archie, MO	6921590	10/19/2015	16
South Grand River at Archie, MO	6921590	1/25/2016	< 15
South Grand River at Archie, MO	6921590	3/28/2016	21
South Grand River at Archie, MO	6921590	5/10/2016	86
South Grand River at Archie, MO	6921590	7/15/2016	118
South Grand River at Archie, MO	6921590	9/26/2016	105
South Grand River at Archie, MO	6921590	10/11/2016	18
South Grand River at Archie, MO	6921590	1/4/2017	< 15
South Grand River at Archie, MO	6921590	3/28/2017	74
South Grand River at Archie, MO	6921590	5/22/2017	60
South Grand River at Archie, MO	6921590	7/7/2017	59
South Grand River at Archie, MO	6921590	9/15/2017	< 15
South Grand River at Archie, MO	6921590	10/13/2017	28
South Grand River at Archie, MO	6921590	1/4/2018	< 15
South Grand River at Archie, MO	6921590	3/26/2018	19
South Grand River at Archie, MO	6921590	5/21/2018	172
South Grand River at Archie, MO	6921590	7/20/2018	196
South Grand River at Archie, MO	6921590	9/14/2018	16
South Grand River at Archie, MO	6921590	10/12/2018	73
South Grand River at Archie, MO	6921590	2/12/2019	175
South Grand River at Archie, MO	6921590	3/12/2019	53
South Grand River at Archie, MO	6921590	4/22/2019	42
South Grand River at Archie, MO	6921590	5/16/2019	38
South Grand River at Archie, MO	6921590	8/1/2019	41
South Grand River at Archie, MO	6921590	9/26/2019	19
South Grand River at Archie, MO	6921590	10/30/2019	182
South Grand River at Archie, MO	6921590	1/7/2020	< 15
South Grand River at Archie, MO	6921590	3/10/2020	792
South Grand River at Archie, MO	6921590	7/9/2020	72
South Grand River at Archie, MO	6921590	8/11/2020	48
South Grand River at Archie, MO	6921590	9/22/2020	25
South Grand River at Archie, MO	6921590	10/8/2020	< 15
South Grand River at Archie, MO	6921590	1/22/2021	< 15
South Grand River at Archie, MO	6921590	3/22/2021	44
South Grand River at Archie, MO	6921590	5/17/2021	752
South Grand River at Archie, MO	6921590	7/6/2021	43
South Grand River at Archie, MO	6921590	8/30/2021	20
South Grand River at Archie, MO	6921590	10/12/2021	64
South Grand River at Archie, MO	6921590	1/3/2022	< 15

Site Name	USGS Station	Date	TSS (mg/L)
South Grand River at Archie, MO	6921590	3/8/2022	17
Big Creek near Blairstown, MO	6921720	10/9/2008	78
Big Creek near Blairstown, MO	6921720	11/4/2008	19
Big Creek near Blairstown, MO	6921720	1/6/2009	19
Big Creek near Blairstown, MO	6921720	3/24/2009	324
Big Creek near Blairstown, MO	6921720	5/19/2009	76
Big Creek near Blairstown, MO	6921720	7/7/2009	62
Big Creek near Blairstown, MO	6921720	9/24/2009	57
Big Creek near Blairstown, MO	6921720	10/28/2009	60
Big Creek near Blairstown, MO	6921720	11/17/2009	105
Big Creek near Blairstown, MO	6921720	12/22/2009	< 15
Big Creek near Blairstown, MO	6921720	1/21/2010	347
Big Creek near Blairstown, MO	6921720	2/5/2010	< 15
Big Creek near Blairstown, MO	6921720	3/10/2010	53
Big Creek near Blairstown, MO	6921720	4/27/2010	146
Big Creek near Blairstown, MO	6921720	5/27/2010	226
Big Creek near Blairstown, MO	6921720	6/23/2010	73
Big Creek near Blairstown, MO	6921720	7/23/2010	50
Big Creek near Blairstown, MO	6921720	8/10/2010	44
Big Creek near Blairstown, MO	6921720	9/29/2010	36
Big Creek near Blairstown, MO	6921720	10/28/2010	53
Big Creek near Blairstown, MO	6921720	11/16/2010	49
Big Creek near Blairstown, MO	6921720	12/8/2010	< 15
Big Creek near Blairstown, MO	6921720	1/26/2011	< 15
Big Creek near Blairstown, MO	6921720	2/25/2011	604
Big Creek near Blairstown, MO	6921720	3/10/2011	80
Big Creek near Blairstown, MO	6921720	4/14/2011	36
Big Creek near Blairstown, MO	6921720	5/10/2011	56
Big Creek near Blairstown, MO	6921720	6/29/2011	32
Big Creek near Blairstown, MO	6921720	7/28/2011	< 30
Big Creek near Blairstown, MO	6921720	8/23/2011	162
Big Creek near Blairstown, MO	6921720	9/23/2011	42
Big Creek near Blairstown, MO	6921720	11/8/2011	184
Big Creek near Blairstown, MO	6921720	12/1/2011	35
Big Creek near Blairstown, MO	6921720	12/8/2011	< 30
Big Creek near Blairstown, MO	6921720	1/6/2012	19
Big Creek near Blairstown, MO	6921720	2/10/2012	29
Big Creek near Blairstown, MO	6921720	3/16/2012	52
Big Creek near Blairstown, MO	6921720	4/4/2012	89
Big Creek near Blairstown, MO	6921720	5/18/2012	39
Big Creek near Blairstown, MO	6921720	6/14/2012	30

Site Name	USGS Station	Date	TSS (mg/L)
Big Creek near Blairstown, MO	6921720	7/12/2012	28
Big Creek near Blairstown, MO	6921720	2/7/2013	28
Big Creek near Blairstown, MO	6921720	3/26/2013	40
Big Creek near Blairstown, MO	6921720	4/17/2013	50
Big Creek near Blairstown, MO	6921720	5/14/2013	52
Big Creek near Blairstown, MO	6921720	6/18/2013	1330
Big Creek near Blairstown, MO	6921720	7/26/2013	23
Big Creek near Blairstown, MO	6921720	8/20/2013	38
Big Creek near Blairstown, MO	6921720	9/5/2013	33
Big Creek near Blairstown, MO	6921720	11/13/2013	< 30
Big Creek near Blairstown, MO	6921720	11/26/2013	32
Big Creek near Blairstown, MO	6921720	1/8/2014	< 15
Big Creek near Blairstown, MO	6921720	2/18/2014	70
Big Creek near Blairstown, MO	6921720	3/27/2014	25
Big Creek near Blairstown, MO	6921720	4/24/2014	69
Big Creek near Blairstown, MO	6921720	5/13/2014	50
Big Creek near Blairstown, MO	6921720	6/3/2014	57
Big Creek near Blairstown, MO	6921720	7/30/2014	27
Big Creek near Blairstown, MO	6921720	8/14/2014	92
Big Creek near Blairstown, MO	6921720	9/19/2014	33
South Grand River below Freeman, MO	6921582	11/19/1997	< 1
South Grand River below Freeman, MO	6921582	1/14/1998	10
South Grand River below Freeman, MO	6921582	6/1/1998	1
South Grand River below Freeman, MO	6921582	8/20/1998	23
South Grand River below Freeman, MO	6921582	11/18/1998	14
South Grand River below Freeman, MO	6921582	1/26/1999	12
South Grand River below Freeman, MO	6921582	6/16/1999	92
South Grand River below Freeman, MO	6921582	8/11/1999	22
South Grand River below Freeman, MO	6921582	11/8/1999	12
South Grand River below Freeman, MO	6921582	1/5/2000	3
South Grand River below Freeman, MO	6921582	5/23/2000	75
South Grand River below Freeman, MO	6921582	7/18/2000	37
South Grand River below Freeman, MO	6921582	11/20/2000	< 10
South Grand River below Freeman, MO	6921582	1/16/2001	22
South Grand River below Freeman, MO	6921582	5/9/2001	73
South Grand River below Freeman, MO	6921582	7/18/2001	56
South Grand River below Freeman, MO	6921582	10/17/2001	61
South Grand River below Freeman, MO	6921582	11/13/2001	16
South Grand River below Freeman, MO	6921582	12/18/2001	20
South Grand River below Freeman, MO	6921582	1/23/2002	12
South Grand River below Freeman, MO	6921582	2/20/2002	82

Site Name	USGS Station	Date	TSS (mg/L)
South Grand River below Freeman, MO	6921582	3/4/2002	< 10
South Grand River below Freeman, MO	6921582	4/23/2002	160
South Grand River below Freeman, MO	6921582	5/15/2002	108
South Grand River below Freeman, MO	6921582	6/11/2002	40
South Grand River below Freeman, MO	6921582	7/10/2002	40
South Grand River below Freeman, MO	6921582	8/13/2002	41
South Grand River below Freeman, MO	6921582	9/25/2002	23
South Grand River below Freeman, MO	6921582	10/21/2002	10
South Grand River below Freeman, MO	6921582	11/14/2002	< 10
South Grand River below Freeman, MO	6921582	12/13/2002	< 10
South Grand River below Freeman, MO	6921582	1/7/2003	22
South Grand River below Freeman, MO	6921582	2/11/2003	28
South Grand River below Freeman, MO	6921582	3/5/2003	24
South Grand River below Freeman, MO	6921582	4/10/2003	28
South Grand River below Freeman, MO	6921582	5/30/2003	36
South Grand River below Freeman, MO	6921582	6/19/2003	43
South Grand River below Freeman, MO	6921582	7/23/2003	17
South Grand River below Freeman, MO	6921582	8/22/2003	12
South Grand River below Freeman, MO	6921582	9/23/2003	12
South Grand River below Freeman, MO	6921582	11/10/2003	11
South Grand River below Freeman, MO	6921582	1/13/2004	< 10
South Grand River below Freeman, MO	6921582	3/10/2004	44
South Grand River below Freeman, MO	6921582	5/7/2004	30
South Grand River below Freeman, MO	6921582	7/20/2004	44
South Grand River below Freeman, MO	6921582	9/22/2004	60
South Grand River below Freeman, MO	6921582	11/3/2004	38
South Grand River below Freeman, MO	6921582	1/11/2005	56
South Grand River below Freeman, MO	6921582	3/22/2005	13
South Grand River below Freeman, MO	6921582	5/6/2005	16
South Grand River below Freeman, MO	6921582	7/22/2005	44
South Grand River below Freeman, MO	6921582	9/30/2005	25
South Grand River below Freeman, MO	6921582	11/15/2005	15
South Grand River below Freeman, MO	6921582	1/13/2006	< 10
South Grand River below Freeman, MO	6921582	3/17/2006	37
South Grand River below Freeman, MO	6921582	5/17/2006	29
South Grand River below Freeman, MO	6921582	7/14/2006	92
South Grand River below Freeman, MO	6921582	9/11/2006	39
South Grand River below Freeman, MO	6921582	11/27/2006	17
South Grand River below Freeman, MO	6921582	1/12/2007	11
South Grand River below Freeman, MO	6921582	2/9/2007	14
South Grand River below Freeman, MO	6921582	3/28/2007	42

Site Name	USGS Station	Date	TSS (mg/L)
South Grand River below Freeman, MO	6921582	4/17/2007	90
South Grand River below Freeman, MO	6921582	5/4/2007	600
Weableau Creek near Collins, MO	6920580	5/8/2007	13
South Trib. Muddy Creek nr Harrisonville, MO	3844410942043	4/29/1992	20
South Trib. Muddy Creek nr Harrisonville, MO	3844410942043	5/20/1992	32
South Trib. Muddy Creek nr Harrisonville, MO	3844410942043	6/17/1992	132
Muddy Creek nr Harrisonville, MO	3845250942233	4/30/1992	31
Muddy Creek nr Harrisonville, MO	3845250942233	5/20/1992	40
North Trib. Muddy Creek nr Harrisonville, MO	3846130942231	4/29/1992	9
North Trib. Muddy Creek nr Harrisonville, MO	3846130942231	5/20/1992	6
North Trib. Muddy Creek nr Harrisonville, MO	3846130942231	6/17/1992	9